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GUIDELINES FOR QUALITY ASSURANCE PROGRAMS FOR MOBILE SOURCE EMISSIONS MEASUREMENT SYSTEMS: PHASE II. HEAVY-DUTY DIESEL ENGINES

Rod Pilkington, et al

Olson Laboratories, Incorporated

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16. ABSTRACT

Quality Assurance guidelines for Heavy-Duty Diesel Engines Mobile Source Emissions Measurement Systems are presented with the concept of a total Quality Assurance System. The guidelines apply to Quality Assurance Principles and techniques in the areas of procurement, standards and calibration, test quality control, data validation and corrective action. Model Quality Management Procedures are presented to describe the relationships and responsibilities of the various organizational elements in accomplishing the quality functions.

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GUIDELINES FOR QUALITY ASSURANCE PROGRAMS FOR MOBILE SOURCE EMISSIONS MEASUREMENT SYSTEMS:

PHASE II, HEAVY-DUTY DIESEL ENGINES - QUALITY ASSURANCE GUIDELINES

by

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June 1975

EPA REVIEW NOTICE

This volume has been prepared by Olson Laboratories, Incorporated consistent with the Environmental Protection Agency Quality Assurance principles and concepts and with the Environmental Protection Agency Mobile Source Testing Practices at Ann Arbor, Michigan.

The guidelines and procedures are generally applicable to mobile source testing operations and are intended for use by those engaged in such measurement programs

It is requested that recipients and users of this document submit any comments and suggestions to the Project Officers.

Mention of trade names or commercial products does not constitute Environmental Protection Agency endorsement or recommendation for use.

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FOREWORD

All mobile source testing facilities have some elements (activities) of a quality assurance system built into their routine testing operations. These activities may not have been identified and/or integrated into a formal quality assurance program. It is the objective of these guidelines to provide guidance to both (1) facilities which desire to organize an integrated quality assurance program, and (2) facilities which may have already organized towards an integrated quality assurance program, but may desire to review their program as a result of the recommendations and suggestions included in these guidelines. The extent of implementation of these guidelines will depend upon the requirements of each individual test facility.

EXECUTIVE SUMMARY

Quality Assurance guidelines for heavy duty diesel emission measurements are presented in this document. The guidelines are modeled after the concept of "total quality assurance" developed in recent years to meet the quality requirements of industrial programs. Many of the quality concepts presented in this document are presently utilized as part of the overall management program of numerous organizations.

In order to evaluate this concept in terms of mobile source emissions, the existing testing facilities at the EPA, Ann Arbor facility and Olson Laboratories were studied for the purpose of identifying those elements requiring quality consideration.

Basic concepts of quality assurance as they apply to the measurement of mobile source emissions involve such areas as procurement control, test quality control, data validation, corrective action, standards and calibration. The guidelines offer guidance in the application of quality assurance techniques in these areas.

The measurement system used for heavy duty diesel engines is described in detail in Volume I, and Test Procedures to meet the applicable requirements of the Federal Register for the 1975 model year, used by the EPA, Ann Arbor facilities appear in Volume II.

Methods of performance checks and preventive maintenance are discussed. Quality management procedures and responsibilities of the quality functions are included as Appendix C to Volume I. Suggested formats for documentation of test data, inspection reports, failure reports, and other form requirements of a quality assurance program are specified.

Statistical methods are a valuable tool in the quality assurance program. Pertinent statistical methods are described with specific applications in emission testing. Test variability is discussed and test variables have been identified. Methods for controlling or reducing test variability are described.

The report is divided into three parts, (1) a general guideline (Volume I) containing quality functions and provisions which are generally applicable to organizations performing emission measurements (2) quality management procedures (Volume I, Appendix C) which define the organizational procedures to be used and assign responsibilities for the quality functions of a model quality assurance program (3) test procedures (Volume II) written for the EPA laboratory in Ann Arbor. A document control system is incorporated to facilitate updating of these procedures as required by changes in the measurement system.

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Section 1

INTRODUCTION

The Quality Assurance Staff of the EPA Quality Assurance and Environment Monitoring Laboratory, Research Triangle Park, North Carolina is responsible for the administration of a Quality Assurance Program for air measurement systems resulting from the implementation of the Clean Air Act. Standards for the emissions from light and heavy duty mobile sources have been promulgated and procedures published for the measurement of their emissions and certification. Quality assurance guidelines, however, have not been previously specified for these mobile source emission measurement procedures. Such quality assurance programs are necessary to assure the integrity of the data resulting from these tests. This report presents guidelines for quality assurance programs for measurement systems used in mobile source testing according to the applicable requirements of the Federal Register for the 1975 model year.

The guidelines for the Quality Assurance Program for mobile source measurement systems are prepared in four phases.

- Phase I - For light duty gasoline powered vehicles (cars and trucks)
- Phase II - For heavy duty diesel engines
- Phase III - For light duty diesel powered vehicles (cars and trucks)
- Phase IV - For heavy duty gasoline engines

This document presents the guidelines for implementing a Quality Assurance Program for the measurement of emission from heavy duty diesel engines (Phase II). Guidelines for the other phases are reported in separate documents.

1.1 OBJECTIVE AND SCOPE OF GUIDELINES

The measurement system for heavy duty diesel engines consists of the testing, calibration and analytical requirements, the operational and measurement procedures used, and the operational and measurement data obtained. The primary objective of this program was to analyze this system and apply the principles and techniques of modern quality assurance systems to the total testing process to assure the validity and reliability of the tests and the resulting test data.

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These guidelines provide information on general quality methods which may be used in emission testing. They were primarily designed for use by management and supervisory personnel involved in the development or operation of quality programs. Upper management may use the guidelines to evaluate the quality programs which presently exist within their own laboratory or organization.

1.2 FORMATION OF QUALITY ASSURANCE GUIDELINES

These guidelines have been written in two volumes. Volume I contains the general guidelines which may be applied to almost any mobile source testing facility. Appendix C of Volume I contains general Quality Management Procedures (QMP) which define those functions identified as being necessary in a quality program. Volume II contains the detailed testing procedures which are used by the EPA Ann Arbor facility for 1975 certification testing.

The quality assurance guidelines for heavy duty engine emission measurement systems are contained in Sections 1 through 8, with all references appearing in Section 9. A summary of the contents of each section is as follows

1.2.1 Section 1 Introduction

A description of the background, objective and organization of the guidelines.

1.2.2 Section 2 Organizing For Quality

A typical Quality Assurance Organization is presented. Quality functions are identified and the various key elements of a quality program are described.

1.2.3 Section 3 Measurement System Analysis

A description of the measurement system defining the equipment, test procedure specifications and tolerances, quality provisions and other requirements necessary for emission testing of heavy duty diesel engines is presented in a matrix format.

1.2.4 Section 4 Guidelines for Performance Audits and Maintenance Procedures

General guidelines are presented for performance inspection and maintenance of instruments and equipment used in the measurement systems. Preventive maintenance programs are described for increasing the reliability and efficiency of the test equipment.

1.2.5 Section 5 Quality Assurance Guidelines for Documentation Of The Measurement System

Guidelines for the development of a documentation system are presented with representative forms, a description of the manuals, data recording, and failure analyses used by a Quality Assurance program.

1.2.6 Section 6 Application of Statistical Quality Assurance Methods To The Emission Test System

Basic statistical techniques such as control charts, analysis of variance and data validation as applied to a quality system are described.

1.2.7 Section 7 Analysis of Variability in the Measurement Of Emissions From Heavy Duty Diesel Engines

Sources of variability are identified and, where possible, quantified to show their effect on the data. A mathematical model selected to give emissions similar to the 1975 Federal emission standards and to show the effect of the variability in data inputs on mass emissions is discussed.

1.2.8 Section 8 Quality Assurance System (On Site) Survey

A procedure and survey form for conducting a Q.A. survey of a laboratory conducting heavy duty diesel emission testing is presented.

1.2.9 Appendices

Statistical techniques and nomenclatures appear in Appendix A-1. Appendix A-2 contains control chart multiplication factors. Appendices B-1 and B-2 include a glossary of terms and a list of abbreviations commonly used in the measurement system.

Section 2

ORGANIZING FOR QUALITY

There are several ways in which a quality assurance program may be incorporated into an organizational structure. The management level at which this function is introduced can greatly determine the effectiveness of any quality assurance program. Therefore, it is necessary in the early stages of quality program planning to study existing functions and responsibilities of each group or department within an organization. The scope of an organization studied should be determined by defining all departments involved in the quality assurance program and the management level at which the quality responsibility is introduced into an organization.

Basically a facility can be divided into four major management functions, Quality Assurance, Data Analysis, Administrative Services and Laboratory Operations. A typical function/responsibility chart will show the four primary functions and the various subfunctions considered to be necessary in a quality organization. The subfunctions should maintain a high degree of flexibility, with assignments made on the basis of manpower proficiency and availability within the major departments. Management should conduct frequent reviews of the effectiveness of the delegated authorities and assigned responsibilities in order to make decisions on possible reassignments or establishing new subgroups as necessary.

A summary of the four primary functions follows.

- Quality Assurance - Has the overall responsibility for insuring adherence to the quality requirements recommended by EPA to comply with Federal regulations through all phases of testing emissions from heavy duty engines.
- Data Analysis - Develops computer programs and processes and monitors test-related data to insure the accuracy and reliability of the emission measurement. Maintains data files of test information and provides statistical programs to assist quality assurance in the improvement of test data.
- Administrative Services - Performs all the necessary peripheral functions required by the laboratory such as purchasing, facility engineering, contracts administration, and the training and certification of personnel.

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- o Laboratory Operations - Performs emission tests on heavy duty engines in accordance with documented procedures. Is responsible for the calibration, maintenance and control of the equipment used in the facility.

2.1 OPERATIONS MANAGEMENT

Upper management should actively participate in establishing quality policies, quality objectives and plans for meeting these objectives. However, instead of providing active leadership of the quality function, upper management may choose to delegate authority for this leadership to some subfunction with a direct line of authority from upper management. A positive management attitude towards quality should stimulate an aggressive quality consciousness among all employees. In establishing a quality assurance program, it is important that the organization be structured to produce a high degree of quality and communication among functional groups with a minimum of personal friction and overlap of authority.

A separate mechanism should be established to assist in integrating these responsibilities, measuring their success, and performing functional responsibilities not assigned to other groups. This mechanism is Quality Assurance Management.

A typical functional organization chart for an emission measurement system is presented in Figure 2-1. The actual organizational chart at a given facility will depend largely on the size of the operation and the assignment of the quality assurance responsibilities. Assignment of the functions should be on the basis of "best able" to accomplish the job rather than trying to set up an "ideal" organization. These functions will be discussed under two major topics; the Quality Assurance Management, and the Emission Test Facility Management.

2.1.1 Quality Assurance Management

It is the primary responsibility of quality assurance to assure the accuracy, precision and completeness of the data from the test system by assisting and integrating the quality development, quality maintenance and quality improvement efforts of the various groups in the organization. The quality assurance program should stress prevention rather than after-the-fact correction of errors on involved tests. Quality assurance also has the overall responsibility for assuring (1) adherence to the procedures required by the applicable Federal regulations and specific contract requirements and (2) adherence to adequate quality control practices.

The functional responsibilities assigned to Quality Assurance Management as shown on the functional chart (Figure 2-1) are procurement control, test quality control, corrective action, standards and calibrations, data validation, deficiency review and audit. To accomplish these functions, the Quality Assurance Management may require assistance from the other groups in the organization or from outside sources. For example, the Data Validation group might utilize the Data Analysis section to perform the statistical or other analyses of data they require. The Standards and Calibration group might purchase certified gas standards from outside suppliers. It must be remembered, however, that assignment of the responsibility for total quality assurance to a particular section does not relieve the other functional groups from performing their assigned quality responsibilities.

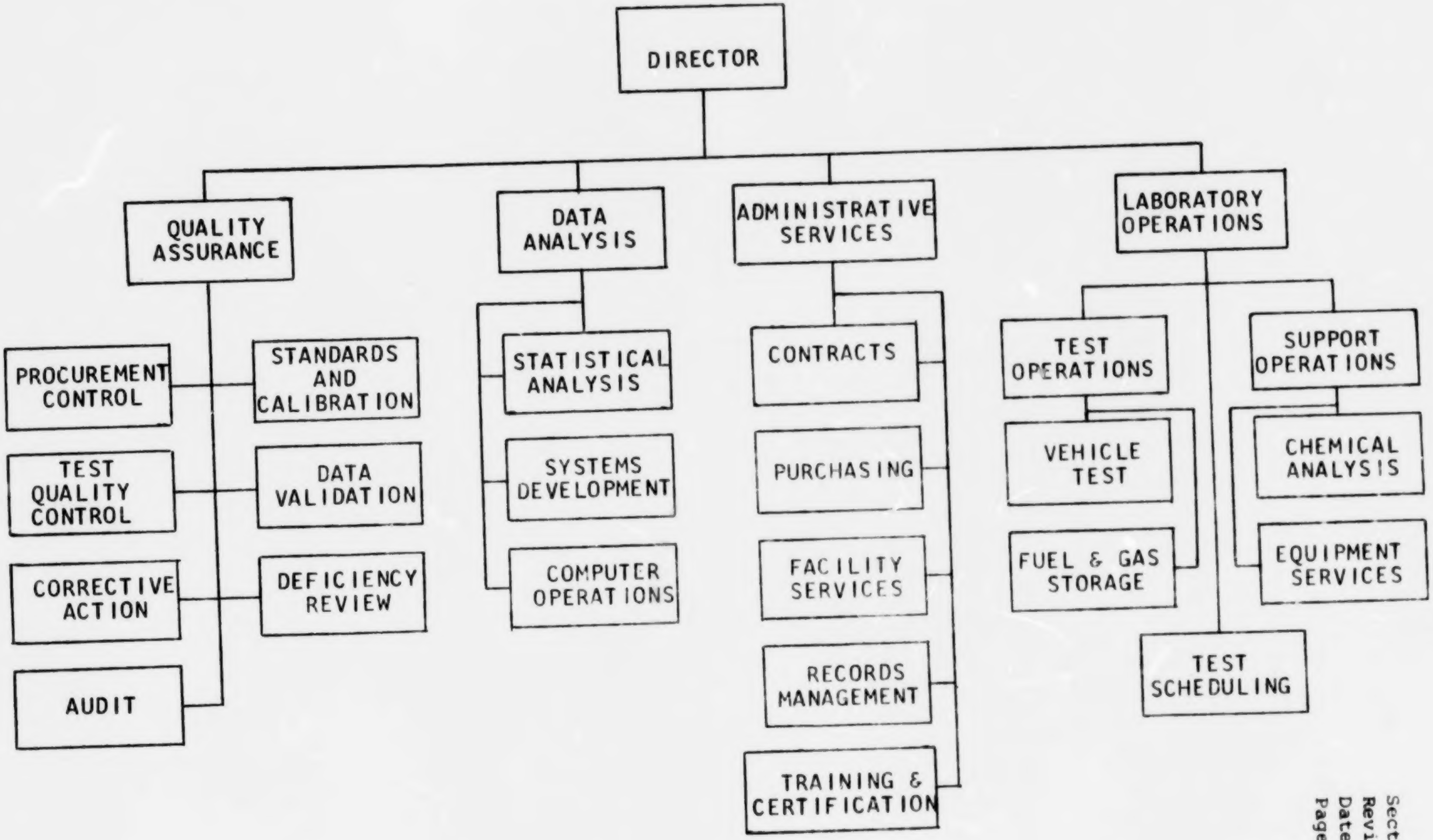
Procurement Control

A test facility purchases equipment, supplies and services from outside sources. The function of Procurement Control is to assist Purchasing in determining qualified suppliers and to assure quality requirements are met by monitoring an order from its inception to completion. This is accomplished in three basic steps.

- Procurement Document Review. The purchase request and the related program are reviewed by Quality Assurance to determine if it includes the correct and adequate description, specifications and requests for analysis and certification when required. In addition, standard purchase order paragraphs are incorporated covering such items as warranty, materials of construction, packaging and shipping information, disposition of rejected material and failure to meet specified requirements or delivery time.

- Supplier Review. A request for quote on the purchased material should be sent out to at least three suppliers unless for some reason the material or service is available from only a single source. An actual on-site supplier review is usually unnecessary; however, responding suppliers should be reviewed by Procurement Control on the basis of past performance and ability to meet specifications of the purchase request. Many of the problems encountered in purchasing equipment and instruments can be avoided by careful procurement document review.

- Receiving Inspection. After the supplier is selected, Purchasing issues a purchase order including all the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LABORATORY OPERATIONS
TEST OPERATIONS
VEHICLE TEST
FUEL & GAS STORAGE
SUPPORT OPERATIONS
CHEMICAL ANALYSIS
EQUIPMENT SERVICES
TEST SCHEDULING

Figure 2-1. FUNCTION/RESPONSIBILITY CHART

requirements contained in the original request. When the material is received, it is subjected to the appropriate receiving inspection to insure that all the requirements of the purchase order are met. Receiving inspection issues a receiving report noting any discrepancies. This is sent to Purchasing and maintained in a supplier file by Procurement Control. Should corrective action be required, Procurement Control will initiate a request for corrective action which is sent to the supplier through purchasing. Procurement Control will then follow up this request to assure supplier compliance.

Procurement Control is concerned with those items, materials and services that can affect the quality of the test data. A list of these items, materials and services should be generated by and jointly agreed upon between Quality Assurance and Purchasing.

In an emission test facility a minimum of the following items should be subjected to a procurement document review on an initial order basis, with an analysis of any discrepancies/failures that may occur.

1. Fuels, pure gases, and other chemicals
2. Calibration gases
3. Filtering or gas absorbing material (i.e., dryrite, ascarite, charcoal, etc.)
4. Fuel Flow Meters
5. Replacement parts for calibration, analytical and/or test equipment
6. Analytical instruments or systems
7. Engine Dynamometers
8. Air Measurement Systems
9. Any sampling equipment used in the analytical process, such as tubing, flow controllers, meters, pumps, valves, flowmeters and sample temperature controllers
10. Computer systems

11. Temperature and pressure measuring and controlling items
12. Chart recorders and chart paper
13. Standards and calibration test instruments
14. Engine diagnostic equipment
15. Fuel conditioning system (Heat exchangers, surge tanks, fuel pumps, etc., as required)
16. Special instrumentation/equipment designed in-house and purchased from outside suppliers (i.e., engine inlet air plenum, filter holders, exhaust systems, etc.)
17. Standard reference materials (SRM) such as NBS Certified weights, smoke capacity filters, and calibration gas mixtures

In addition to the purchasing-procurement control relationship, it is important that the person or group requesting an item be involved in the initial review. The concept of cost usage should be considered in the initial procurement review. (Ref. 2-1.) A careful analysis of the utility of a particular item should be performed by reviewing the specified requirements with the user. In many cases, items are purchased because they are considered to be the "best" on the market. However, often a more cost-effective item can be utilized without affecting the quality desired. For example, if calibration gases are subjected to analysis during a receiving inspection and measured against primary standards, it would be of no value to order gases with a certified ±1.0 percent analysis. This would be especially true if the gases are to be utilized as routine span gases. Gases other than primary standards can be ordered without analysis or with a specified "make" tolerance (a guarantee that the actual value will fall between certain limits), or batch analysis at a lower cost. The effect on quality would be negligible. On the other hand, if these same gases were to be used as a primary standard, the ±1 percent tolerance might not be good enough if the desired end result of the instrument being calibrated was ±2 percent. Usually a factor of four is considered acceptable from the primary to the secondary standard, which would dictate a required accuracy of ±0.5 percent for the primary standard and might require purchase of NBS standard reference material or gravimetric blend.

Test Quality Control

Since Quality Assurance has the final responsibility for assuring the quality of the emission data, it must define and implement the necessary quality controls. To improve the quality of the data and decrease the number of voided tests, prevention rather than correction should be stressed. Many of the quality provisions are presently required by the Federal Register, or by good engineering practices developed from experience with the analytical process. These provisions are presented in the following section which describes the test procedures. Test quality control is a continuing process since the system is constantly generating new data and subject to change. The data generated can be used to identify those areas which have need for better control and those areas which may be over-controlled. As new instruments are introduced into the system, their characteristics and operating parameters must be carefully studied for revision of quality control procedures. The methods for evaluating the system can be functional or statistical. Functional evaluations would uncover particular operation needs and requirements such as calibration and maintenance. Statistical evaluation involves a system study utilizing data generated by the system. This data history might be used to construct control charts, define acceptable limits or predict a need for calibration or preventive maintenance. These techniques are discussed to a greater degree in Section 6. Quality analysis should also be applied to evaluation, development or research programs where the test data will be used for some special reason such as determining the effectiveness of tune-ups on emissions. In this case, new variables which require controlled provisions will be added to the system.

Corrective Action

The feedback of error information to the originator of the error, with a request for corrective action to prevent recurrence of such an error, is a vital part of an effective quality assurance system. The corrective action system must be provided with a "closed loop" mechanism, namely, persistent follow-up until satisfactory corrective action has been accomplished and documented. Failure to follow up on a corrective action request nullifies the power of this important quality tool. Further discussion of corrective action is presented in Sections 4 and 5.

Standards and Calibration

A primary function in any system is the maintenance of standards and calibration for measuring devices. Emissions are determined on a mass basis from gas concentration, volume, flow rates and density measurement. In the early days of testing, all measurements and emission standards were based on a volumetric measurement. Measurements were made by non-dispersive infrared instruments which were calibrated from standards usually prepared by partial pressure and analyzed by gas chromatography.

The "state of art" for preparing gas mixtures has improved greatly since the early days of vehicle testing. Stable blends are prepared routinely by gas suppliers. NBS and EPA have been cooperating in a program to prepare Standard Reference Material (SRM) i.e., NBS certified gas mixtures, for emission testing. Gravimetric blends have been prepared by the EPA for carbon monoxide, carbon dioxide, nitric oxide, and propane mixtures.

The following standard reference gases are available from NBS:

SRM's 1665 - 1669 Propane in air
SRM's 1673 - 1675 Carbon dioxide in nitrogen
SRM's 1677 - 1681 Carbon monoxide in nitrogen
SRM's 1683 - 1687 Nitric oxide in nitrogen

Any emission testing facility should maintain a complete set of instrument calibration standards which are traceable to the EPA primary standards. Working standards, used on a daily basis are analyzed using this calibration set. Annual correlation of the calibration set with EPA is recommended. Another possible method of checking these standards is through a gas cross-referencing program whereby cylinders of unknown blends are sent to each test site on a quarterly basis and analyzed against the standards. The reported analyses are treated statistically and those analyses which are suspect may indicate a need for auditing the particular calibration gases involved.

In addition to the calibration of the analytical instruments there are several other tests or calibrations required within the measurement system.

Other instruments which require calibration are:

1. Engine diagnostic equipment
2. Temperature recorders
3. Barometers
4. Hygrometers
5. Engine dynamometers
6. Recorders or output measuring devices.
7. Smokemeters
8. Fuel flow meters

Quality Assurance should be responsible for maintaining the calibration procedures and records in a file by specific item and updating and reviewing the calibration results as they are performed. The Laboratory Operations in turn should report all calibrations results to Quality Assurance.

Deficiency Review

In any measurement system, deficiencies, repetitive errors and an inordinate void test rate may be encountered. When any of these situations are discovered, a review should be initiated by Quality Assurance Management to determine the cause and recommend a plan for correcting the situation. This review is sometimes conducted by a Deficiency Review Committee which is composed of representatives from the departments involved, Management, and Quality Assurance. Their recommendations are presented to the Laboratory Management. Quality Assurance has the responsibility for measuring the effect of implementing these corrective actions. This review process should be repeated until the desired results are achieved.

Data Validation

A control network must be established to assure a smooth flow of all data collected during an emission test. Data Validation should perform the control function and also check the data forms to confirm the validity of the results and assure the data is within specified limits. This function should be independent of the test technicians and should report directly to Quality Assurance Management or the Laboratory Director. Validation is accomplished usually by personnel with extensive experience in emission testing. The actual checks should be done against specified documented control limits. Data transfers should be verified and all forms checked for completeness. Invalid or incomplete data should be reported to the testing supervisor and Quality Assurance. The rate of error should be monitored to determine trends and the need for corrective action. Data validation procedures will vary with the size and structure of the laboratory. Their merit will be evaluated in terms of user acceptability of the validity of the data. An example of a Data Validation network is described and illustrated in QMP No 6.6 HD, Appendix C of this report.

Audits

Independent and random audits should be made to further assure the reliability of the measurement system. Two types of audits are generally considered.

- o Performance Audit - a planned independent random check of the data output and personnel in order to evaluate the quality of the output from the total system. Section 4.0 discusses performance audits in greater detail.

- o System Survey - a systematic on-site qualitative review of facilities, equipment, training, procedures, recordkeeping, validation and reporting aspects of a total (quality assurance) system, to arrive at a measure of the capability and ability of the system. Even though each element of the system survey is qualitative in nature, the evaluation of each element and the total may be quantified on some subjective basis. A typical quality system survey is discussed in Section 8.

There are several performance audits which are done in the emission measurement system. Routine performance checks are not considered as part of the audit system since they are performed on a scheduled rather than a random basis and are usually performed by the test operators as an integral part of their activities. However, an auditor may use any of the performance checks as an audit check. These checks are discussed in Section 4.

Audits are important to the Quality Assurance Management as the only objective method available to determine the data quality and to assure that the emission test is being conducted according to the prescribed procedures.

The audit report is the most important part of the audit procedure, but to be effective, it must reach the management level having the authority to initiate corrective action; Quality Assurance Management should have the authority to shut down any part of the testing system producing invalid test data until the non-conforming condition is corrected.

Other Quality Assurance Elements

There are other elements which should be considered in a total quality assurance program, such as:

Reliability is becoming an increasingly important consideration in emissions measurement due to the complex systems involved. The probability of failure tends to increase as equipment becomes more complex. A comprehensive reliable testing program must rely on many tools:

1. Accurate and complete record-keeping, with a data feedback loop built into the program.

2. Specific preventive maintenance schedules including replacement schedules to remove and replace low reliability parts before they reach wear-out stage.

3. Complete descriptions of the equipment or instruments that are required to undergo reliability testing. These descriptions will include specifications for both quality and reliability.

4. Concise specifications for the performance of tests, including meticulous attention to the ambient conditions - such as number of operating cycles and times, temperatures, shock, pressures and vibrations - that are to prevail during testing.

5. Definite sampling procedures, sample sizes, criteria for judging the success or failure of a test and acceptance and rejection values for action on a measurement.

6. Knowledge of the calculated sampling risks, such as those embodied in operating characteristic curves or tabulated data on the probabilities of sampling errors.

A failure analysis report should be prepared for each occurrence of equipment failure. There is a further discussion of failure reporting and analysis in Section 5.

Configuration and Documentation Control in a testing laboratory is primarily concerned with assuring that all similar equipments have the same configuration and that all hardware and document changes, including computer program revisions have been recorded. There is a further discussion of these controls in Section 5.

Quality costs should be readily identifiable in any effective quality assurance system. These costs are usually categorized into:

1. Prevention Costs
2. Appraisal Costs
3. Internal Failure Costs
4. External Failure Costs

Reference 2-3 discusses these costs in greater detail.
The benefits from implementing a quality cost program include:

1. Overall quality performance can be measured in terms easily understood by management.

2. Problem areas can be defined.

3. Input for budgeting purposes can be easily obtained.

4. Cost savings can be readily identified.

A system should be designed to collect and report these costs accurately, completely and in a meaningful manner, and the data should be properly organized and available when needed.

2.1.2 Emission Test Facility Management

Basically, the management of an emission test facility can be divided into four major activities; Quality Assurance Management, as discussed in the previous section, Administration, Data Analysis and Laboratory Operations which includes Test Operations and Support Operations. In a total quality assurance program, the organizational structure may appear as shown in Figure 2-1, with Quality Assurance on the same management level as Administration and Laboratory Operations. There is general agreement among the experts in the field of quality assurance that the introduction of a quality function below this level will not provide the necessary line of authority to succeed.

A brief description of the primary functions performed by the departments are:

Administrative Services

Administrative Services performs all the necessary peripheral functions required by the emissions facility such as contracts, purchasing, facility services, personnel, records management, training and certification.

1. Purchases from the Quality Assurance Approved Supplier List all materials, equipment, instruments, expendable items, office equipment, etc., which affect test data quality.

2. Routes purchase requests for those items which affect test data quality to Quality Assurance for approval of specifications and drawings and inclusion of standard quality clauses where applicable.

3. Requests approval and review of suppliers' product from Quality Assurance as required.

4. Provides for all facilities engineering requirements which may have an effect on data quality such as plumbing, heating, cooling, electrical wiring, ventilation and fuel storage.

5. Initiates, recommends, and implements safety programs and procedures for the facility which meet personnel, equipment and building requirements in accordance with OSHA, EPA and State regulations.

6. Formulates, recommends, and implements administrative policies in accordance with the Quality Management Procedures. (See Appendix C.)

7. Controls and maintains inventory of all parts, supplies, and equipment used in the normal operation of the emission test facility.

8. Responsible for training personnel involved in any phase of vehicle emission measurement and should assist in training quality assurance personnel. Administrative Services should assist Test Operations and Quality Assurance in the development of adequate training programs and the evaluation of programs using written or practical "hands-on" examinations. A report describing examination development methodology is available from the Environmental Protection Agency. (Ref. 2-2.)

Data Analysis

Data Analysis develops computer programs, processes and monitors test-related data to assure the accuracy and reliability of the emission measurements. Maintains data files of test results and provides statistical programs to assist Quality Assurance in the evaluation and improvement of test data quality.

1. Develops and processes computer programs for the reduction of test data to provide emission results on a grams per mile basis for carbon monoxide, hydrocarbons, carbon dioxide and nitric oxide.

2. Maintains all test data in a data file.

3. Provides statistical analysis for Quality Assurance requirements such as determination of acceptable test parameter limits, preparation of control charts, analyses of variance and cost effectiveness analyses.

4. Develops computer programs for calibration data, maintains calibration data file, and computes instrument calibration curves. Informs Quality Assurance and Test Operations when calibration and maintenance has not been performed according to the intervals prescribed by Support Operations.

5. Assists Quality Assurance in monitoring all data to verify the accuracy and reliability of emission measurements.

6. Maintains the paperwork inventory for calibration gas cylinders.

7. Assists Quality Assurance and Laboratory Operations in the construction of mathematically correct formulas for the reduction of data for non-routine test programs.

8. Assists Quality Assurance in developing and implementing correlation and audit programs to assure the reliability of the data on a "cell-to-cell" basis, and for comparison with other laboratories performing emission testing.

9. Documents all program changes, forms, etc.

Laboratory Operations

Laboratory Operations has the responsibility for the daily operation of the vehicle test section. This includes the performance of emission testing, calibration, maintenance, sample analysis, the supervision of personnel, equipment and vehicles utilized in the performance of emission testing and implementation of in-process quality control checks.

Quality Management Procedure Number 2.3 in Appendix C details the primary functions of the Test Operations and Support Operations departments.

Section 3

MEASUREMENT SYSTEM ANALYSIS

A total Measurement System can be defined as an orderly arrangement consisting of the analytical method, the test sampling procedure, the instruments or analyzers, the supporting functions, the management organization and the technicians or personnel involved in performing specific functions within the system. Applying this definition to the measurement system for heavy duty diesel engine emissions, the process is composed of:

- The test procedure defined by the Federal regulations
- The preparation of the diesel engine for the emissions test
- The exhaust emission sample transfer and analytical console consisting of NDIR instruments for the measurement of carbon monoxide (CO) and nitrogen oxides (NO_x), a heated flame ionization instrument (HFID) for measurement of hydrocarbons (HC), a full flow optical smokemeter mounted near the exhaust plume for measurement of diesel smoke.
- The Laboratory Operations management including Test Operations and Support Operations

This measurement system was subjected to a functional analysis to determine and define the basic elements which require attention in a total quality assurance program.

3.1 APPLICABLE FEDERAL REGISTER PROCEDURES

Measurement Systems for which Quality Assurance guidelines and procedures have been developed are defined in the Federal Register. Those portions of the Federal Register which define the measurement systems covered by this document are:

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	Date	Vol.	No.	Page
1.	November 15, 1972	37	221	24293-24314
2.	June 28, 1973	38	124	17149-17162
3.	October 31, 1973	38	209	30082
4.	November 21, 1973	38	225	32138
5.	November 23, 1973	38	225	32258
6.	February 27, 1974	39	40	7562-7568

The cut-off date for Federal Regulations considered in this report was July 31, 1974. Subsequent revisions should be incorporated into this document by the user.

The paragraphs of the Federal Register subparts defining the scope of the measurement system for heavy duty diesel engines appear in Table 3-1.

In addition to the Federal Register the following Society of Automotive Engineers publications were used:

- SAE J177 - Measurement of Carbon Dioxide, Carbon Monoxide and Oxides of Nitrogen in Diesel Exhaust
- SAE J244 - Measurement of Intake Air or Exhaust Gas Flow of Diesel Engines
- SAE J215 - Continuous Hydrocarbon Analysis of Diesel Emissions
- SAE J255 - Diesel Engine Smoke Measurement

3.2 ELEMENTS OF A MEASUREMENT SYSTEM FOR HEAVY DUTY DIESEL ENGINE EMISSION MEASUREMENT

A requirement of a total Quality Assurance Program is to have control at all important stages of a process. In this measurement system, an analytical process, it is necessary to first identify its functional elements. In order to categorize these elements and the related tasks the measurement system was divided into the following operations.

- Engine-dyno preparation
- Engine-dyno checkout
- Engine test cycle preconditioning
- Smoke measurement
- Smoke emission test cycle
- Intake air measurement
- Measurement of fuel flow

- Gaseous Emission test cycle
- Measurement of gaseous emissions
- Data collection and reduction

A summary of the emission measurement procedure for both smoke and gaseous emissions is presented in Table 3-2. The overview represented by this matrix was designed to give a general understanding of the process involved in exhaust emission testing. However, it is not intended to include every detail required for this measurement. The information discussed in this table consists of:

- A brief description of the tasks
- Applicable Federal Register paragraphs
- Applicable EPA, Ann Arbor, test procedure numbers
- Specification and tolerances included in the Federal Register, and from engineering practices such as the SAE recommended practices
- Quality provisions
- Invalid test (determination)
- Corrective action required
- Training and skill level required

Table 3-1. EMISSION REGULATIONS FOR HEAVY DUTY ENGINES

Subpart I - Engine smoke exhaust emission regulations for new diesel heavy duty engines

APPLICABLE REVISIONS*	SECTION	TITLE
2, 6	85.802	Definitions
	85.803	Abbreviations
2	85.874-9	Test procedures
	85.874-10	Diesel fuel specification
	85.874-11	Dynamometer operation cycle for smoke emission tests
	85.874-12	Dynamometer and engine equipment
	85.874-13	Smoke measurement system
	85.874-14	Information to be recorded
2	85.874-15	Instrument checks
	85.874-16	Test run
	85.874-17	Chart reading
	85.874-18	Calculations

Subpart J - Engine exhaust gaseous emission regulation for new diesel heavy duty engines

APPLICABLE REVISIONS*	SECTION	TITLE
2, 3	85.902	Definitions
	85.903	Abbreviations
2	85.974-9	Test procedures
	85.974-10	Diesel fuel specifications
	85.974-11	Dynamometer procedures
	85.974-12	Dynamometer and engine equipment
2	85.974-13	Sampling and analytical methods
	85.974-14	Information to be recorded
	85.974-15	Calibration and instrument checks
2	85.974-16	Test run
	85.974-17	Chart reading
2, 3, 4	85.974-18	Calculations

*2) 28 June 1973, 3) 31 October 1973, 4) 21 November 1973, 5) 23 November 1973, 6) 27 February 1974

Table 3-2. FEDERAL EMISSION TEST PROCEDURE - SMOKE AND GASEOUS EMISSIONS

PROCEDURE OR TASK	BRIEF DESCRIPTION	FR REF EPA TP NO.	SPECIFICATION OR TOLERANCE-FED. REG.	SPECIFICATION: SAE OR ENG. PRACT.	QUALITY PROVISIONS	TEST INVALID	CORRECTIVE ACTION	TRAINING OR SKILL LEVEL
A Engine-Dyno Preparation	The engine is installed on the test bed and coupled to the dyno. Auxiliary equipment, exhaust and inlet air systems are installed on the engine.	85.874-12 85.974-12 TP-750	Exhaust system shall be 12 ±5 ft. from manifold or VEE. Backpressure = ±0.2" Hg of Mfr. Spec. @ Max. hp. Inlet restriction ±1" H_2O of Mfr. Spec. @ Max. Air flow. Final 2 ft. straight and round dia. Determined by hp.	MEAPC Advisory Circular No. 22A, shipping instructions and preparation of heavy duty engines for EPA testing.	Installation checked by supervisor prior to engine start up. Inlet and outlet P. recorded and checked by data validation.	Improper installation resulting in out of tol. restriction. Incorrect Mfr. spec. used.	Correct installation and repeat test. Determine correct specifications.	Heavy duty engine mechanic with knowledge of dyno operation and installation procedures
B Engine-Dyno Checkout	The engine is operated at idle and load conditions to check for proper operation, make final adjustment and determine that engine speed, torque and fuel flow meet Mfr. specifications.	85.874-16(b) TP-750	Adjustments must be completed in less than 1 hour running time for zero hour test.	Listen for internal noises, such as piston slap, knocks, tap and gear noises that indicate irregularities in engine operation.	Preliminary checkout of engine parameters and associated measurement devices such as torque, speed, T&P fuel flow meters.	Engine irreg. detected. Inability to achieve proper inlet and/or outlet restrictions Mfr. Spec. not achieved by engine or dyno.	Shut down engine and notify supervisor and Mfr. Rep. Determine restriction problem and correct.	Engine dyno operator with working knowledge of heavy duty engine operations and performance.
C Engine test cycle preconditioning	Engine is operated at maximum rated horsepower for 10 min. or until temperature and oil pressure reach equilibrium	85.874-9 85.874-16 TP-751	Inlet Air 68-86°F Bar 28.5-31.0 in. Hg. for preconditioning - Test governor and fuel system adjusted to Mfr. Spec.		Final equipment check before test start.	Engine not fully warmed prior to start of test.	Repeat test	As above in B
D Smoke measurement and test cycle	The warm engine is run through three sequences of idle, acceleration, and lugging modes	85.874-9 85.874-16 TP-751	Idle time 5-5.5 min. accel. 200 ±50 rpm above idle for 35 sec. Accel. to 85-90% rated speed in 5 ±1.5 sec. Accel. shall be linear ±100 rpm. Lugging ±50 rpm of specified speed	Test cycle repeated until 3 consecutive valid tests have been achieved. Opacity filters checked by EPA every 6 months.	Smoke meter calib. traceable to NBS. All test data checked by data validation	Incorrect time, load or speed. Excessive Instrument drift.	Repeat test Correct inst. problem.	As above with smokemeter experience or training.
E Intake air measurement	In order to determine emissions on a mass basis, the mass of intake air must be measured as a function of time for each mode of the gaseous cycle.	85.974-13(c) TP-752	SAE recommended practice J244	ΔP accuracy of 0.5 percent of idle flow. Leakage test to within ±0.5 percent of idle flow.	Leak check of air measurement system. LFE calibration traceable to NBS. Transducers calibrated against manometer before and after test.	Leaks on change in ΔP. read out calibration will invalidate test.	Correct problem and rerun test	Training in use and installation of LFE and manometers.
F Measurement of Fuel Flow	In order to determine the total mass of the exhaust, the mass of fuel must be measured per unit time. Mass Ex = Mass Air + Mass Fuel.	85.974-14(m) TP-755 TP-756	SAE J244 SAE J916B Fuel temperature must be 100 ±10°F at pump inlet	±1 percent of observed reading.	Data checked by validation - fuel temp and mass flow. Flowmeter calibrated with dead weight tester.	Failure to record fuel flow during any mode. Flowmeter malfunction detected.	Repeat test	Instruction in operation of fuel flow meter.
G Gaseous Emission test cycle	The test is designed to determine the brake-specific emissions of hydrocarbons, carbon monoxide and oxides of nitrogen when an engine is operated through a cycle which consists of three idle modes and five power modes at each of two speeds which span the typical operating range of diesel engines.	85.974-9,11,16 TP-753	Speed ±50 rpm Torque ±2 percent of the max. torque and the test speed. Warmup for 10 min. or equil. T&P at rated speed and and max. hp. Operate 10 min. each mode. (See C. Preconditioning.) RPM and torque changes in first minute. Torque and rpm spec. must be met during last min. of mode. Fuel-type 1-D or 2-D.	SAE J1003	If a delay of more than 10 min. occurs repeat test from mode 1. Time, rpm, torque checked by data validation.	Mode time in excess of 10 minutes, rpm, torque or time out of tolerance	Repeat test from mode 1.	Instruction in operation of dyno controls.
H Measurement of HC, CO NO and O_2 in diesel exhaust	Measurements are made of the exhaust concentrations during the last minute of each mode. O_2 is measured only if required for correction of the HFID reading	85.974-13,15,16 TP-753 TP-754	SAE J177 Sect. 2.1, 2.2, 2.3.1 SAE J215 Sect. 2.1, 2.2, 3 and 7 Auxiliary instruments calibrated according to good practice. Instrument zeros checked as necessary to maintain test validity. Zero and span at start, mode No. 7, end of test. Record analyzer response during 10 min. test, sample last 5 min. of test	Calibrate monthly, 5-point calib. ±2 percent, weekly checks. 2 Hr. min. warmup. Span 75-95 percent. Sample dryer. HC range 10-6,000 PPMC response 90 percent - 10 sec. Detector and oven temp. cont. ±2°C. Range 150-200°C. Probe - multihole, 80 percent across exhaust pipe, heated sample line 150-200°C ±2°C of set point.	Optimize detector response. Weekly O_2 interference check Optimize system operating temperature. H_2O, CO, interference check, monthly. Data validation	Span or zero shift. Incorrect sample time. Incorrect span deflection. Inadequate or too low temp. cont. calib. overdue	Correct span and zero shift and repeat from last check point. Repeat test cycle as required. After correcting out-of-spec. condition.	Training in operation of analytical console. Knowledge of calib. maint. and minor adj. of instruments.
I Data collection and reduction	For complete list of required information see 85.974-17. Ambient condition fuel and air flow, analyzer output are recorded/validated and the data reported in grams per brake horsepower.	85.974-16,17,18 TP-751, 752, 753, 754, 755, 756, and 851	RPM/Torque/intake air/restriction exh. and air/fuel flow/air flow, recorded during last 5 min. each mode. Fuel flow during idle and 2 percent may be measured. Following or prior to running cycle. Analyzer response integrated for last 60 seconds of each mode. Correct NO_x for humidity. Weighting factor Idle 0.2, other modes 0.08	Mass flow rate SAE J244. Mass ex = Mass air + mass fuel Correct sample. Comp. to wet basis SAE J177	Data validation check computer - inst. output alignment each test. Sample transport time checked each test.	Detection of error or abnormality at this point requires invalidation of test.	Repeat complete test sequence	Training in data validation, chart reading, data inspection, and reduction, computer operation as required.

Section 4

GUIDELINES FOR PERFORMANCE AUDITS AND MAINTENANCE PROCEDURES

Independent performance audits are conducted by a supervisor or auditor to determine if the data collected is valid. This is accomplished by defining system performance characteristics and acceptable limits, and auditing to assure the instrumentation/equipment, and data are acceptable. The occurrence of invalid data, non-acceptable instrumentation and suspect values should be documented and corrective action initiated to restore confidence in the system.

Preventive maintenance routines can affect precision, accuracy and reliability of a measurement system used in mobile source emission monitoring. Adequate routine preventive maintenance procedures will minimize equipment failures. Maintenance schedules should be related to the purpose of the project, normal audit intervals, frequency of usage, and frequency of failures. Reporting procedures should include standard checklists for ease of reporting and document control.

4.1 PERFORMANCE AUDITS

Performance audits are those techniques implemented/used by the Quality Assurance management to evaluate the total measurement system. These audits may involve the total system or specific portions of the measurement system. The techniques normally applied for performance audits include the collection of normal operation data (i.e., emission data, calibrations, etc.), replicate samples from the sampling or analysis system and the subsequent plotting of the results on control charts (see Section 6.2 for methods of plotting control charts). Further audits may be made by the use of operational checks, visual checks and standard reference samples. The audit techniques should be applied without the knowledge of the system operator/analyst, if possible, to eliminate any bias, and to assure that the results are representative of actual conditions.

A list of typical performance audits with associated checks are given in Table 4-1.

Audits may be independent of or in conjuction with normal quality checks. Independence can be achieved by having an operator not normally assigned to the emission system in question perform the audit. An alternate method is to provide a standard reference sample of unknown

Table 4-1. PERFORMANCE AUDITS (TYPICAL) - FOR A HEAVY DUTY DIESEL EMISSION MEASUREMENT SYSTEM

AUDIT CATEGORY	CHECKS
Instrumentation	1. Observe calibration procedures. 2. Check calibration records and tags to insure proper intervals are followed. 3. Check maintenance records and all log books. 4. Perform or observe an emission test using test cell equipment instruments. Check for system drift, noise, gain, response. Check for the reproducibility of the span and sample.
Operator - Dyno/Analytical	1. Observe the technician performing the test. Check that the forms are being properly filled out during the test. 2. Check conformance to test procedure requirements. 3. Ask the technician questions concerning his job to determine that he possesses the required skill level.
Equipment - Sampling System Inlet Air System	1. Perform leak check. 2. Inspect filters, sample conditioning items for proper maintenance.
Equipment - Fuel Handling	1. Check for proper calibration and maintenance of fuel measurement system. 2. Take sample of fuel from system for analysis. Note color of diesel fuel.
Equipment - Auxiliary	1. Check calibration, maintenance and operation of all auxiliary equipment located or used in the test cell such as portable tachometer, engine diagnostic, and safety alarms and interlocks.
Data Processing	1. Check computer alignment with instrument meter output. 2. Check for proper data validation procedures and that proper authorization for the test sequence is being followed. 3. Select data files at random and check all forms and records. 4. Reduce all data manually to check its accuracy. 5. Check data transfers and test engine information for correctness.

value (concentration) to the operator and request that he analyze and report the concentration values following normal operating procedures (Ref. 4-1.)

In conducting the performance audit, various items should be identified to assure all pertinent features of the system are identified. The following criteria must be identified for each audited item of the measurement system.

- Characteristics
- Acceptance criteria
- Frequency of checks
- Method (Procedure) used to perform check
- Corrective action requirements
- Recording of audit results

4.1.1 System Performance Characteristics

Factors to be considered in the establishment of a system's quality characteristics are quality of specifications, quality of conformance and time-oriented factors such as availability, reliability and maintainability. Specifications must have adequacy, attainability, and compatability with the environment of the testing laboratory. Quality of conformance is the result of numerous variables: test equipment, tools, supervision, workmanship, etc. Availability is measured by the extent to which a user can obtain service when he wants it. Reliability is classically defined as "the probability of a system performing without failure, a specified function, under given conditions, for a specified period of time." Maintainability is concerned with methods to improve the maintenance of long-life systems, by planned preventive maintenance and unscheduled maintenance which consists of restoring service in the event of a failure. (Ref. 4-2.)

The total measurement system consists of the analytical method, sampling method, operational conditions, the instrument or analyzer, calibration, computation, data validation and the operator. The critical characteristics of this complex system should be identified by functional analysis and/or sensitivity analysis (Ref. 4-3.) After identifying the critical characteristics, the analysis should be extended to determine a means of controlling them and for detecting non-acceptable performance.

Any feature (attribute, property, output, etc.) of the sampling and/or analytical system which is required to achieve fitness for use is normally classified as a quality characteristic. For example, any measurable or recordable output generated from the system or component, such as flow rates, calibration data, concentration measurement and gain settings exhibited by an analyzer are quality characteristics. Each of these characteristics are subject to a performance audit (Ref. 4-3).

By classifying those numerous quality characteristics of the system which may affect the precision and accuracy of system output, a valuable tool for weighing the relative importance of system performance is provided. This type of classification enables the quality effort to concentrate on those characteristics which have a major effect on the system output, thereby assuring quality and continued measurement at a minimum quality cost.

4.1.2 Acceptance Criteria

Each characteristic that is being subjected to a performance audit has to be evaluated on the basis of the acceptance criteria for that particular characteristic. The development of these criteria requires much discussion and common consent among parties of interest. The acceptance criteria for a Heavy Duty Diesel Emission Measurement System are related to the requirements of the Federal Register (see Table 4-2). An expanded version of this table is shown as Table 3-2.

Acceptance criteria will vary somewhat from one laboratory to another, however, they must never be more lenient than those promulgated in the Federal Register. The above referenced Tables are not necessarily a complete list of acceptance criteria. Each laboratory should first list the characteristics of their particular system and refer to these Tables for the corresponding criteria. If one cannot be found for a particular characteristic, good engineering judgment must be used to determine the acceptance criteria, keeping in mind the effect it may have on overall test variability.

The economic impact of acceptance criteria should be taken into consideration. There have been situations in which an urge for perfection has overshadowed the use of some equally applicable alternative criteria available at a considerably reduced cost. For example, a contractor specifies that a certain name brand instrument or analyzer be used to fulfill a contract requirement. In such cases, even though the contracted laboratory had an instrument already in use, equivalent in every respect, they would have to incur an extra cost despite the fact that the data quality would not be improved.

4.1.3 Frequency of Checks

Performance audit intervals are usually conducted on a non-routine basis as required by the particular system. Frequent audits are required with new equipment, procedures and personnel. As experience is gained with the system, audits may be performed less frequently. However, they are necessary for a functional quality program and failure to perform the audits may result in higher rate of invalid tests or less reliability of the emission data.

Table 4-2. FEDERAL REGISTER SPECIFICATIONS
HEAVY DUTY DIESEL EMISSION MEASUREMENT

SUBPART I

<table>
<tr><th>REFERENCE PARAGRAPH</th><th>PROCEDURE OR EQUIPMENT DESCRIPTION</th><th>SPECIFICATION OR TOLERANCE</th></tr>
<tr><td>85.802
(J).902</td><td>Definition - Zero (0) hours
1974 Model Year</td><td>Point after assembly line operations and adjustments and before 1 additional operating hour has been accumulated.</td></tr>
<tr><td>85.874-1</td><td>Smoke Exhaust Emission Standard

Note: For information purposes only, this does not directly relate to testing specifications, however, it could be referenced to as an engine variable and specification.</td><td>Shall not exceed:

20 percent during engine acceleration mode

15 percent during engine lugging mode

50 percent during the peaks in either mode.</td></tr>
<tr><td>85.874-10
(J).974-10</td><td>Diesel Fuel Specifications (Testing) (See Section 85.874-10 (c) for fuel used for service hour accumulation).</td><td>
<table>
<tr><th>Item</th><th>ASTM Test Method No.</th><th>Type 1-D</th><th>Type 2-D</th></tr>
<tr><td>Octane</td><td>D613</td><td>48-54</td><td>42-50</td></tr>
<tr><td>Distillation range</td><td>D86</td><td></td><td></td></tr>
<tr><td>IBP °F</td><td></td><td>330-390</td><td>340-400</td></tr>
<tr><td>10 percent point °F</td><td></td><td>370-430</td><td>400-460</td></tr>
<tr><td>50 percent point °F</td><td></td><td>410-480</td><td>470-540</td></tr>
<tr><td>90 percent point °F</td><td></td><td>460-520</td><td>550-610</td></tr>
<tr><td>EP °F</td><td></td><td>500-560</td><td>580-660</td></tr>
<tr><td>Gravity, ° API</td><td>D287</td><td>40-44</td><td>33-37</td></tr>
<tr><td>Total sulfur present</td><td>D129 or
D2622</td><td>0.05-
0.20</td><td>0.2-
0.5</td></tr>
<tr><td>Hydrocarbon composition</td><td>D1319</td><td></td><td></td></tr>
<tr><td>Aromatics, percent</td><td></td><td>8-15</td><td>27 (Min)</td></tr>
<tr><td>Paraffins, Napthenes, Olefins</td><td></td><td>Remainder</td><td>Remainder</td></tr>
<tr><td>Flash point, °F (Min)</td><td>D93</td><td>120</td><td>130</td></tr>
<tr><td>Viscosity, centistokes</td><td>D415</td><td>1.6-2.0</td><td>2.0-3.2</td></tr>
</table>
</td></tr>
<tr><td>85.874-11</td><td>Cycle for Smoke Emission Tests

Note: Engine must be warmed up and preconditioned according to 85.874-16(c). Engine may be run for more than three cycles as no limit has been placed on number of cycles or the time period for completing the cycles. Data must be reported for three successive cycles</td><td>Idle

Time = 5 to 5.5 seconds
Speed = recommended low idle
Load = minimum obtainable

Acceleration

i - 200 ± 50 RPM within 3 sec. above low idle
ii - 85-90 percent rated speed in 5 ± 1.5 sec. linear ± 100 RPM
iii - speed of maximum rated torque or 60 percent of rated speed (whichever is higher) within ± 50 RPM
iv - 90-100 percent rated speed in 10 ± 2 seconds

Lugging Mode

i - Max. hp @ rated speed
ii - max. torque or 60 percent of rated speed, whichever is higher in 35 ± 5 seconds - linear rate ± 100 RPM

Repeat cycle 3 times</td></tr>
<tr><td>85.874-12
(J).974-12</td><td>(a) Dynamometer Specifications
NOTE: This specification is inadequate due to the variable range of engines. It would be difficult to write any one specification to cover all engine families.</td><td>Adequate characteristics to perform the test cycle.</td></tr>
</table>

Table 4-2. FEDERAL REGISTER SPECIFICATIONS
HEAVY DUTY DIESEL EMISSION MEASUREMENT (Continued)

SUBPART I (Continued)

REFERENCE PARAGRAPH	PROCEDURE OR EQUIPMENT DESCRIPTION	SPECIFICATION OR TOLERANCE
85.874-12 (J).974-12 (Cont'd)	(b) Engine Cooling System NOTE: Engine temperature	Capable of maintaining the engine at normal operating temperature during the cycle. Non-insulated 15 ± 5 feet from the exhaust mainifold, or cross over junction. Exhaust back pressure must be within ± 0.2 inch Hg. of the upper limit at maximum rated hp. as established by manufacturer.
	(c) Exhaust System	Terminal 2 feet of exhaust pipe. Circular cross section straight, cut off squarely with a diameter in accordance with rated horsepower Maximum rated horsepower — Exhaust Pipe Diameter (inches) Less that 101 — 2 101 - 200 — 3 201 - 300 — 4 301 or more — 5
	(d) Engine Air Inlet System	Inlet restriction must be within ± 1 inch of water of the upper limit for the engine operating condition which results in maximum air flow as established by the manufacturer.
85.874-13	Smoke Measurement System	1. Continuous reading. 2. Full-flow light obscuration meter. 3. Light beam right angle axis to plume. 4. Light source - incandescent lamp operated not less than 15 percent of mfg. spec. 5. Beam collimated to diameter of 1.125 inches. 6. The angle of divergence of the collimated beam shall be within 4° included angle. 7. Detector sensitivity as restricted to the visual range and comparable to that of the human eye. 8. A collimating tube with apertures equal to the beam diameter is attached to the detector to within 16° included angle: Recorder 1. Continuous, variable speed 0.5 to 8.0 inches/min. with automatic marker or chart paper equivalent to 1 sec. intervals. Full scale response = 0.5 sec. 2. Recorder scale, linear, 0-100 percent capacity with 1 percent resolution.
85.874-13	Recorder For RPM and Torque Measurement	RPM resolution = 30 RPM Torque Resolution = 10 lb.-ft.
85.874-13	Smoke Measurement System Installation	Distance from the optical centerline to the exhaust pipe outlet shall be 5 ± 1 inch with the full flow of the exhaust stream centered between the source and detector apertures and on the axis of the light beam. Instrument stabilization time = 15 minutes.
85.874-15	Calibration of smokemeter - deviations from nominal opacity of the filter. NOTE: Opacity filters used for calibration should be traceable to an acknowledged reference standard such as NBS.	Deviations greater than 1 percent shall be corrected.

**Table 4-2. FEDERAL REGISTER SPECIFICATIONS
HEAVY DUTY DIESEL EMISSION MEASUREMENT (Continued)**

SUBPART I (Continued)

REFERENCE PARAGRAPH	PROCEDURE OR EQUIPMENT DESCRIPTION	SPECIFICATION OR TOLERANCE
85.874-16	Test Cell Ambient Conditions	Inlet Air = 68-86°F Bar = 28.5 - 31.0 Hg
85.874-16	Engine Preconditioning	10 min @ max. rated hp.
85.874-16	Smoke Measurement Drift Test Zero or Full Scale	± 2 percent Opacity
	SUBPART J	
85.974-1	Exhaust gaseous emission standard for 1974 model year diesel engines	HC + NO_x = 16 grams per brake horsepower hour CO = 40 grams per brake horsepower hour
85.974-11	Heavy duty diesel test cycle	Mode No. — Engine Speed — Percent Load 1 — Low Idle — 0 2 — Intermediate — 2 3 — do — 25 4 — do — 50 5 — do — 75 6 — do — 100 7 — Low Idle — 0 8 — Rated — 100 9 — do — 75 10 — do — 50 11 — do — 25 12 — do — 2 13 — Low Idle — 0 Allowable deviation during last minute of each mode. Speed ± 50 RPM Torque = ± 2 percent of max torque at test speed
85.974-13	Sampling and Analytical Methods	
	o Carbon Monoxide and Nitric Oxide Measurement	SAE recommended practices No. J177 Sections 2.1 and 2.2
	o Hydrocarbon Measurement	SAE recommended practices No. J215 Sections 2.1 and 2.2
	o Intake Air Flow	SAE recommended practices No. J244
85.974-15	Calibration and Instrument Check	SAE-RPN J177 Section 2.3.1 SAE-RPN J215 Sections 3 and 7

Table 4-2. FEDERAL REGISTER SPECIFICATIONS
HEAVY DUTY DIESEL EMISSION MEASUREMENT (Continued)

SUBPART J (Continued)

REFERENCE PARAGRAPH	PROCEDURE OR EQUIPMENT DESCRIPTION	SPECIFICATION OR TOLERANCE	
85.974-16	Test Run Conditions	Inlet Air	68-86°F
		Fuel	100 ± 10°F
	NOTE: Time of modes should give some tolerance to allow for time measurement inaccuracies.	Bar	28.5 - 31.0 in. hg.
		Warm Up	10 min. hp - rated speed or until T-P equilibrium
		Time Each Mode	
	NOTE: Test is repeated until valid test is run, number of tests not specified.	Allowable Time	10 minutes
		Between Modes	10 minutes
		Analysis Time	Last 5 minutes each mode
		Engine Speed Load Changes	1st minute each cycle
		Check and Reset Zero and Span	Second idle mode (No. 7)
		End of Test	
		Full scale change greater than 2 percent voids test	

4.1.4 Audit Equipment

In most cases special equipment is not required for an audit function in mobile source emission testing. Audits are usually performed by observation, validation, calculation, checking records and actual use of the emission equipment. An auditor may request primary standards or measurement equipment from the calibration or standards groups for audit purposes. Equipment, if used in the audit must have unquestionable reliability as for example, thermometers certified by NBS for checking ambient temperatures and thermocouples, and recently calibrated gauges. Audit equipment required for checking a characteristic must be clearly specified in the documented audit procedure.

4.1.5 Procedures For Independent Performance Checks

The techniques employed in independent performance audit to evaluate the quality of data produced by part of or the total measurement system usually include the introduction of control samples into the system. The results are subsequently plotted on control charts and evaluated. A detailed discussion of types of control charts is contained in Appendix H of Reference 6-1. Various applications of these charts are shown in Section 6.0. These checks should be made independent of the normal quality assurance checks. A check could be made by a different operator/analyst than the one normally involved in the measuring process. A reference sample of a known concentration of pollutant could be supplied to the operator/analyst with a request that he measure and report its concentration (preferably he would be unaware which is the reference sample).

There are a number of variables that can affect the expected precision and accuracy of measurements made in the total system. Some of these are related to analysis uncertainties and others to instrument characteristics. Table 4-3 summarizes some of the more important variables and how they can be monitored. A discussion of test variability appears in Section 7.

The recommendations from manufacturers of the various types of instrumentation and equipment used in the total measurement system should provide an initial source of information on the methods and frequencies of inspection. These recommendations cannot always be followed as specified due to the numerous sources of variability exhibited by the system. Therefore, alternative methods of frequency determination must be considered. A sensitivity analysis (Ref. 4-4) can provide a basic insight into the frequency of performance audits, and statistical sampling techniques can be used to good advantage.

Table 4-3. EXAMPLE METHODS OF MONITORING VARIABLES

VARIABLE	MONITORING METHOD	FREQUENCY OF CHECK	ACCEPTANCE CRITERIA
1. Calibration Gas Concentration	Measurement of control samples as a part of the independent auditing program.	Verify concentration when initially purchased. Audit concentrations at monthly intervals and/or when desired performance standards cannot be met.	Zero gas with ±0.1 deflection. Span gas within ±0.2 deflection. Concentration should be within ±2 percent of stated value.
2. H_2O/CO_2 Interference Low Range CO-NDIR	Checks performed on an audit basis.	Perform check upon receipt of the CO instrument to confirm that it meets the specified acceptance criteria. Audit at periodic intervals to assure performance standards are met.	See Federal Register, Volume 39, No. 101, Thursday, May 23, 1974, 85.075-20(C) (11).
3. Zero Drift	Zero check and adjustment prior to each test period as part of routine operating procedures.	Perform as a routine operation and periodically as a performance audit.	Drift should not exceed ±1 percent of full scale.
4. Span Drift	Span check and adjustment prior to and following each sampling period.	Perform as a routine operation and as a periodic performance audit check.	Initial and post calibration should agree within ±1 deflection.
5. System Noise	Check the strip charts trace for signs of noise during and after each test period.	Perform on a per test basis. Check during performance audit. Monitor trace as part of chart recorder calibration.	Noise should not exceed ±1 percent of full scale.
6. Temperature Variation	A thermometer or any other temperature indicating device placed near the analyzer or sample system to monitor unusual conditions.	Perform weekly/monthly as part of a performance check.	Should conform to specifications as indicated by manufacturer of each instrument checked.

4.1.6 Reporting and Corrective Action Procedures

The value of any check is increased substantially if it can help prevent repetition of some error which would not have met the acceptance criteria. It is essential that the laboratory quality assurance program includes systematic procedures for recording and analyzing check results, and the determination of the need and implementation of corrective action. Consideration should be given to the potential for incorrect data entry each time a value is recorded, due to human error. These kind of errors are sometimes difficult to detect, and the importance of accuracy in recording results must be continually stressed. Control charts should be used, where appropriate, to monitor data quality. Various statistical techniques, exemplified in Section 6, can be used to analyze check results.

When acceptance criteria are not met, the most effective means of preventing further trouble is to implement corrective action to eliminate the cause of nonconformance. To maintain data quality at an acceptable level, it is essential that the quality assurance system be sensitive and timely in detecting out-of-control or unsatisfactory conditions. The basic steps in setting up a closed-loop corrective action system are (Ref. 4-5):

1. Define the problem.
2. Assign responsibility for investigation of the problem.
3. Investigate and determine the cause of the problem.
4. Develop or determine a corrective action to eleminate the problem.
5. Assign responsibility for implementing the corrective action.
6. Establish effectivity and implement the correction.
7. Verify that the corrective action has eliminated the problem.

The implementation of these steps often requires the cooperation of many individuals and departments. Corrective action requests must be formally documented and reinforced with an effective follow-up system to assure the closing of the loop. Section 5.0 shows the typical flow of the correction action loop with a specific example and forms requirements.

4.2 PREVENTIVE MAINTENANCE

Preventive maintenance, or the lack of it, can affect the precision, accuracy and reliability (see Section 6.0) of a measurement system. The concepts of preventive maintenance are not new; nor are they confined to specific type of industry. Preventive maintenance is as practical to a laboratory situation as it is to have a mechanic check your car at regular intervals.

The principle that underlies preventive maintenance is that every component or system has a basic engineered life. They will be clustered (predictably) if the product is reliable and widely dispersed for products of lesser quality which display erratic performance. For example, suppose the detector in an analyzer has a rated life of 2,000 hours. If the design and quality of both the detector and the analyzer in which it is used are superior, there may be very few failures before 2,000 hours and practically every detector will have to be replaced before 2,500 hours of operation. If the design is defective, however, the failures will be spread over a longer period, starting within the first hours of operation and continuing sporadically until the last detector fails (Ref. 4-6.)

Maintenance factors will affect system reliability (see Section 2.1.1). Some of the factors are:

a. Training, experience and availability of instrument maintenance specialists. Poor maintenance services will increase down-time and mean-time-between-failures, increase costs and cause mistrust of data validity.

b. The physical conditions under which maintenance tasks must be carried out can affect reliability in a like manner, if work must be done in extreme cold, heavy rain or snow or under inadequate lighting conditions. Tied in with these is the presence of adverse factors such as lack of space, proper tools or supplies.

c. Responsibilities for various levels of repair and maintenance should be spelled out so that no preventive maintenance task has been incorrectly assigned.

d. Control of spare parts should be exercised.

    1. Inventory records should be kept to prevent stock-outs and subsequent, increased down-time.

    2. Policy should be established to control cannibalization of parts when short-falls against requisitions or purchase orders occur.

e. Scheduled coordination with calibration activities will save time and reduce maintenance down-time and equipment back-up requirements.

f. Repair reports such as operational logs (Figure 4-9) and corrective action requests and recommendations should be sent through the quality assurance reporting loop.

4.2.1 Preventive Maintenance Procedures

In order to minimize equipment degradation or failure, scheduled (i.e., periodic or routine) preventive maintenance actions must be performed. The manufacturer's instrument/equipment manual is the logical starting place for identifying systems or subsystems that require periodic replacement or maintenance. A more meaningful method of scheduling maintenance is to plot past instrument/equipment performance on control charts (Section 6.0) and identify the optimum maintenance periods from the frequency of malfunctions shown for each piece of equipment.

Servicing and maintenance schedules should relate to the purpose of testing, the environmental influences, the physical location of the equipment/instrumentation, and the level of operator skills. An operational guideline showing time intervals for various types of service, such as routine daily tasks and scheduled checks weekly monthly, quarterly and semi-anually must be developed from control charts and manufacturer's recommendations to assure the quality of the total system. Checklists and station logs must be established and maintained routinely by the system operator/ maintenance staff to record maintenance performed and to insure that maintenance schedules have been met. Service and maintenance must be performed by personnel with the skill level required to assure that efficient and effective repair/replacement is accomplished. In general, station operators should not attempt to perform more than routine (daily) checks or diagnosis of a particular problem; they (the system operators) should definitely not attempt any repairs for which they lack proper training or equipment, or for which the time required would interfere with normal operations.

An example of a routine, daily, preventive maintenance check for mobile source emissions monitoring follows. The items are arranged in a systematic order for ease of checking by the auditor or operator.

Schedule for Daily Start-Up/Servicing (General Guideline)

- Upon arrival start-up all instrumentation
  Note: Some instruments are never turned off while they are "in service" to avoid long warm-up time

- Check and record gain settings for HFID, CO, NO analyzers

- Check and record zero settings for HFID, CO, NO analyzers
- Check working gas cylinders for correct pressures and record pressure
- Check recorders for zero, gain, correlation with computer and paper supply
- Check all system pressures
- Check and record the NO_x analyzer for flow rate, temperature and reactor operating pressure
- Leak check by observing flowmeters and pressure gauges and record results
- Check dynamometer torque by hanging weight on torque arm
- Check smokemeter calibration noise and installation
- Check engine inlet air system
- Purge fuel measuring system and check heat exchanger operation
- Turn on engine cooling system
- Record information on log sheet or log book

Further information concerning pretest preparation may be found in the Test Procedures in Volume II of this report.

Various items from this checklist can be usefully plotted on control charts as shown in Section 6.0.

Figure 4-1 shows a general form that may be used for routine, daily, start-ups and preventive maintenance check sheets.

A system of logs and check sheets (such as those shown in Section 5, and Section 4.2.2) to document that the required preventive maintenance checks have been made and necessary work has been performed, can be in the form of lab books or multiple copy forms. Multiple copy forms are an efficient means by which quality assurance can perform a systematic review of maintenance accomplished during preventive maintenance periods. A maintenance summary should be provided to outline significant corrective maintenance. It should include the replacement of major components and required equipment changes. This is normally an inhouse change required to increase the system efficiency. Analysis of these reports will aid in developing a history of parts used, operations performed and frequency of replacement, for use in determining optimum parts replacement schedules, maintenance schedules and optimum inventory control.

HEAVY DUTY DIESEL ENGINE TEST CELL DAILY START-UP CHECKSHEET

DEPT. NO.	SHIFT	CELL	DATE	P.I.C.

ANALYTICAL INSTRUMENT CALIBRATION

	LEAK CHECK		RNG	GAIN	ZERO	CYCL NO.	CONC	DEFL	PRESS
	FL MTR OBS	MAG OBS	1,000						
			5,000						
CO			2.5						
			500						
HFID			1,000						
			1,500						
NO			6,000						
Zero									

Recorder

Chart Sp	DVM Corr	Gain	Zero

HFID

	Sample	Fuel	Air
Press.			
	Line	Filter	Detector
Temp.			

SMOKEMETER

Filter Readings

10 Percent	20 Percent	40 Percent	Zero	100 Percent	Drift

Alignment: ☐ Lens: ☐ Light: ☐ Purge Air: ☐

Dyno Torque Check Weight: ________ Actual: ________

Inlet Air System ☐ Fuel System ☐ Engine Cooling System ☐

Comments: ____

____

Figure 4-1

4.2.2 Preventive Maintenance Action

This section provides a system of check lists which outline the preventive maintenance actions, frequency of performance, and indications of need for specific system components.

The major system components of Mobile Source Emissions are shown in Table 4-4, along with the frequency requirement. Daily checks such as smokemeter calibration are given in the daily start-up procedure (4.2.1).

For each preventive maintenance period, the checks shown for each type of equipment should be made to assure that the total system retains the precision and accuracy required to produce acceptable data. If a failure is discovered during any preventive maintenance period, a failure report (Figure 5-11, Section 5.2.5) should be filed to document the cause of failure, type of equipment, suggested corrective action and final corrective actions taken. An equipment repair authorization (Figure 5-9, Section 5.2.3) should also be submitted to the particular organization responsible for maintenance/repair, to document that expedient repair or replacement was accomplished and that the costs involved were recorded.

Table 4-4
PREVENTIVE MAINTENANCE SCHEDULE - MAJOR COMPONENTS

MEASUREMENT SYSTEM COMPONENT	FREQUENCY CHECK	REFERENCE CHECKLIST
Smokemeter	6 Months	Figure 4-2
Inlet Air/Exhaust Measurement System	Monthly	Figure 4-3
Analysis System (Includes HC, CO, O_2 NO analyzers)	Weekly Monthly	Figure 4-4 Figure 4-5
Dynamometer (Includes speed and torque meters)	Monthly	Figure 4-6
Related Equipment	Monthly	Figure 4-7 (Ref. 4-6)

Upon completion of the preventive maintenance checks, the supervisor will perform an audit to assure the maintenance efficiency and sign the checklists when satisfied with the results.

PREVENTIVE MAINTENANCE CHECKLIST

DEPT. NO. TRAIN DATE TECHNICIAN

EQUIPMENT: Smokemeter

PERIOD: 6 months

/ / Return optical filters to the EPA for recalibration.

/ / Clean optical lenses and check lamp illumination power.

/ / Check electrical connection to lamp and photo multiplier assembly - Repair/Replace damaged or loose wires/connectors.

/ / Calibrate and service recorder. (Refer to Manufacturer's manual)

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Figure 4-2

PREVENTIVE MAINTENANCE CHECKLIST

DEPT. NO.	TRAIN	DATE	TECHNICIAN

EQUIPMENT: Inlet Air/Exhaust Measurement System.
Laminar flow element

PERIOD: Monthly

/ / Check air filter. Clean with compressed air or replace as required by manufacturer's recommended practice.

/ / Leak check system according to SAE -J244 Section 2.3.1.1.

/ / Clean manometers to remove wall deposits and add new fluid.

/ / Calibrate incline manometer with dead weight tester or micromanometer to assure accuracy and correct fluid specific gravity.

/ / Clean or replace all lines and check connections.

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Figure 4-3

PREVENTIVE MAINTENANCE CHECKLIST

DEPT. NO.	TRAIN	DATE	TECHNICIAN

EQUIPMENT: Analysis System - CO, NO, O_2 and HFID

PERIOD: Weekly

/ / Visual - perform visual inspection on areas of unit that are easily accessible.

/ / Daily Log Book - Inspect daily log book for entries that might be pertinent in effecting proper maintenance or repair.

/ / Calibration Curve (2 Points) - Pass a high and low standard gas through each analyzer after making a set point using a standard reference gas on the high end of the range. If either point is off ±2% or more, investigate further by running complete curve.

/ / HFID Burner Peak - See instrument manual of specific manufacturer. (SAE J215 - Section 3.1.1.1.)

/ / HFID Oxygen Response - Check according to TP-754 Section 8.0, Test Sequence 103.

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Figure 4-4

PREVENTIVE MAINTENANCE CHECKLIST

DEPT. NO.	TRAIN	DATE	TECHNICIAN

EQUIPMENT: Analysis System

PERIOD: Monthly

- ☐ Visual - Perform visual inspection on areas of unit that are easily accessible.
- ☐ Daily Log Book - Inspect daily log book for entries that might be pertinent in effecting proper maintenance and repair.
- ☐ Recharge polarographic oxygen sensor.
- ☐ Perform complete monthly calibration on all analyzers. See Test Procedure TP-203.

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Figure 4-5

PREVENTIVE MAINTENANCE CHECKLIST

DEPT. NO.	TRAIN	DATE	TECHNICIAN

EQUIPMENT: G. E. Engine Dynamometer

PERIOD: Monthly

/ / Visual - Perform visual inspection on areas of unit that are easily accessible.

/ / Daily Log Book - Inspect daily log book for entries that might be pertinent in effecting proper maintenance and repair.

/ / Check oil level at dynamometer support trunnions.

/ / Lubricate - Lubricate points on the dynamometer as indicated in the manufacturer's maintenance manual.

/ / Perform complete monthly calibrations of speed and torque meters. Test Procedure TP-250.

/ / Check hoses and connections for possible leaks during operation.

/ / Clean Water Strainer

- Turn off water supply
- Remove screen
- Clean screen with compressed air
- Replace screen and turn on water

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Figure 4-6

PREVENTIVE MAINTENANCE CHECKLIST

DEPT. NO.	TRAIN	DATE	TECHNICIAN

EQUIPMENT: Individual Instruments

PERIOD: Monthly

Check calibration tag on each of the following instruments for calibration due date. Submit a job request (Section 5.2.3) to the proper service group listing those due for calibration.

/ / Barometer (Test Procedure TP-206)

/ / Fuel Measurement System

/ / Torque and Speed Recorder (RPM)

/ / Hygrometer

/ / MV Recorders-Analytical Console

/ / Manometers (accuracy check)

/ / Pressure Gauges

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Figure 4-7

4.2.3 Maintenance Log Procedures

Any maintenance (whether preventive, routine or emergency) performed on the equipment/instruments required in the measurement of heavy duty engine emissions should be directly recorded into a maintenance log.

The maintenance log, when properly used and maintained provides a valuable tool for documenting equipment breakdown histories, a guide for maintenance scheduling, and a handy reference for troubleshooting problems. Therefore, it is imperative that some sort of maintenance recording procedure is developed and used regularly.

Figure 4-8 is an example of a three-part maintenance log form. The following information should be reported on the form.

1. Responsible department
2. System number (for multi-system facilities)
3. Date of equipment failure
4. Person in charge-technician
5. Description of equipment and model (ex: AIA-1, CO analyzer)
6. Equipment manufacturer (ex: Horiba)
7. Serial number of equipment
8. Time of reported equipment failure
9. Summary of problem; any noticeable discrepancies from normal operating mode
10. Corrective action; include steps taken to repair equipment, parts replaced, and equipment used for repair, or other action taken to preclude recurrence
11. Time and date of effective equipment repair
12. Signature of person performing repair
13. Signature of Supervisor responsible for equipment operation.

MAINTENANCE REPORT

DEPT. NO.	TRAIN	DATE	P.I.C.
1	2	3	4

EQUIPMENT DESCRIPTION: 5

MANUFACTURER: 6

SERIAL NO.: 7

TIME OF FAILURE: 8

SUMMARY OF PROBLEM: 9

CORRECTIVE ACTION: 10

TIME/DATE EQUIPMENT ON LINE: 11

CORRECTIVE ACTION PERFORMED BY: 12

WHITE/FILE CANARY/QUALITY CONTROL PINK/MANAGER

SUPERVISOR 13

Figure 4-8

Section 5

QUALITY ASSURANCE GUIDELINES FOR DOCUMENTATION OF THE MEASUREMENT SYSTEM

The responsibilities of Quality Management have been outlined in Section 2; however, the implementation of the Quality Management function depends upon the documentation of specific quality responsibilities, departmental procedures and the interrelationship of each to Quality Management. The mechanism usually chosen to accomplish this is the development of a Quality Management Procedures Manual. Associated with this manual are the separately documented test or operating procedures used by the various departments for performing their basic functions such as specific emission test procedures, calibration, maintenance, and data analysis.

5.1 DEVELOPMENT OF AN OPERATIONS MANUAL

Mobile source testing facilities generally incorporate some elements of quality planning either formal or informal, into their testing operations. The end product of these facilities is test data, and it is essential that authoritative information and control be implemented to assure that the data produced is accurate and reliable. Information and control can be obtained through the use of formalized quality planning in the form of Quality Management procedures that provide for documentation as objective evidence of information and control.

The Quality Management Procedures Manual specifies the necessary paper work system for the documentation of the various quality functions. A smooth flow of data greatly enhances the auditing portion of the Quality Assurance system. A network of forms to be used in data recording and reporting should be developed along with specific forms instructions and processing procedures. Establishment of a closed loop corrective action process relies on the documentation and distribution of the results of receiving inspections, audits, calibrations, etc.

This report for Phase II of this program has been prepared in two volumes. Volume I contains the Quality Assurance Guidelines for Heavy-Duty Engine Emissions Measurement Systems. The Quality Management

Procedures are included as Appendix C to this volume. Volume II of the report contains a Test Procedures Manual prepared for the EPA Laboratory in Ann Arbor, Michigan. This manual contains:

- Step by step testing procedures for direct use by technicians performing the various portions of the test, inspection, calibrations and analysis.
- Standard data sheets and forms for use in recording and handling operational, inspection, calibration and analytical data and computational processes.

Discussion of the guidelines for the preparation of a Procedures/Operations Manual follows.

5.1.1 Document/Manual Control

The responsibility and procedure for the implementation, preparation, numbering and revision of Quality Management and Test procedures and forms used in the measurement system must be clearly defined. Usually this is a function shared by Quality Management and Administration Services. Response to the changing requirements of the measurement system is of utmost importance. Timely reporting of change notices, review of revisions, maintenance bulletins, etc., will prevent the forms and test procedures manual from becoming obsolete. The effectiveness of document control may be directly judged by the universal use of the forms and the consideration of the Quality Management and Test Procedures manuals as worthwhile references.

In addition, a master file of all procedures and subsequent revisions showing effective dates and cross indexed for ease of reference should be maintained. Responsibility for the actual revision of the distributed manuals should be defined and manuals should be audited on a random basis to determine compliance.

5.1.2 Quality Management Procedures

The Quality Management Procedures Manual included as Appendix C to Volume I of this report divides each department into various functional units. Specific operational functions, authorities, and responsibilities are outlined. In addition, the Quality Assurance provisions are assigned and the interrelationship with other departments are defined.

Specific management procedures are detailed for each function, reflecting the organizational policy on the functional aspects of a Quality Assurance program. Other Quality Management procedures provide the instructions required to implement a Quality Assurance program, defining the purpose and procedure for implementing the policy, including the assignment of functional responsibility. The procedures are usually prepared and administered by the Quality Assurance Management with the direct approval of the Laboratory Director/Manager.

5.1.3 Testing Procedures

The only available published documents outlining the testing procedures to be used to measure the emissions from mobile sources is the Federal Register and the recommended practices of the Society of Automotive Engineers (SAE) (Reference Section 3.1).

It is necessary that the Test Procedures be detailed and developed in a logical sequence. They should cover all phases of the actual procedures performed in conducting an emission test and in calibrating and maintaining the test equipment. The scope of the test procedures manual(s) will be determined by the complexity of the equipment used, the skill level of the people performing the procedures, the number, size and location of the testing units and varied kinds of testing performed in the facility. As a general guide any procedure performed as a matter of routine or on a periodic basis should be documented.

The Test Procedures contained in Volume II of this report have been written in a standardized 13-point format.

1. Purpose - The reason or objective of performing the test is briefly described.

2. Test Article Description - This is a brief description of what is being tested, analyzed, calibrated, etc.

3. References - The Federal Register paragraphs, SAE Procedure, Manual or other documents that were the original source of the procedure are referenced along with literature references which give additional background information on the procedure.

4. Required Equipment - Lists the necessary equipment including model number, manufacturer and other pertinent information.

5. Precautions - Lists safety precautions and points out certain procedures that are critical and require special attention. Although specific safety precautions are documented in this section a general safety program is required by OSHA, especially in larger organizations, and is usually maintained as a separate manual.

6. Visual Inspection - A check of the equipment, hook ups and general configuration of the equipment. For example: a vacuum line disconnected on emission control equipment would have to be connected.

7. Test Article Preparation - Those steps performed immediately prior to the actual test performance. They may be referenced to a prior procedure or, if simple preparation, be outlined in this section.

8. Test Procedure - A numbered sequential step-by-step procedure used to accomplish the objective stated in Paragraph 1 above. The points in the sequence where an entry or data output are required are described and noted in the right hand margin.

9. Data Input - A description of the information and data obtained during the test and the manner in which it should be treated, stored or computed.

10. Data Analysis - A description of the data validation procedure used and any subsequent statistical treatment to assure that it is within acceptable limits, complete, accurate and reliable.

11. Data Output - Descriptions of the data reporting and filing procedure, also if applicable, examples of the computer output format.

12. Acceptance Criteria - A list of predetermined criteria which comprise a valid test and are used in Paragraph 10 for data analysis.

13. Quality Provisions - A description of checks, calibrations, inspections, witnesses, specification, duplicate sampling, etc., specifically incorporated into the test procedure for controlling the quality of the data.

A facsimile of the form used to document the results of the test is included or referenced. This form should also be referenced in Test Procedure, paragraph 8 above.

This format is not the only one which could be selected. There are many acceptable methods for writing laboratory procedures; however, whatever format is selected should be used consistently. The format should be designed to facilitate change, clearly define objectives, and specify the quality acceptance provisions of the test procedure.

5.1.4 Related Information

Other sections as determined by individual needs may be added to a Procedures Manual, such as a separate section on maintenance, categorized by equipment requiring the use of specific procedures not documented previously, particularly when a separate maintenance manual has not been prepared. These could be issued periodically as bulletins.

Special test procedures may also be included to cover interim modifications not requiring procedure change, or special contract requirements for a single program.

A glossary of terms and special sections on theory of operations of the equipment are sometimes included.

In preparing a procedures manual for the first time it is best to follow the rule of "keeping it simple". Complexity and additions will come with use, as the needs are identified through audit and review by Quality Management.

5.2 DOCUMENTATION REQUIREMENTS OF A QUALITY ASSURANCE SYSTEM

The most convenient and systematic way of developing a Quality Assurance Plan or in summarizing and reviewing an existing Quality Assurance program is to prepare a Plan Activity Summary Matrix for each major activity or operation. This matrix will include the documentation requirements of the Quality Assurance system.

For mobile source emission testing the major activities or operations usually included in the plan are:

- Procurement (ordering)
- Procurement (receiving)
- Calibration
- Verification and Correlation
- Test Operations

  Engine Preparation and Installation
  Smoke Emission Test
  Gaseous Emission Test
  Fuel Control

- Data Reduction and Validation
- Preventive Maintenance
- Auditing

For each of the above activities the following items should be considered:

- A list of the characteristics to be checked.
- A list of the acceptable level of quality requirements established by Quality Planning (QA).
- A description of the frequency of checking each characteristic.
- A brief description of the method, equipment or reference standards to be used for checking each characteristic.
- Directions for the inspector to follow if the characteristic does not comply with acceptance limits.
- A description of the type of record in which the accept/reject data is to be reported.

Examples of a Quality Plan Activity Summary Matrix for Procurement (receiving) are given in Tables 5-1 and 5-2. Similar tabular summary matrixes should be prepared and kept up-to-date by the Quality Assurance function for each test facility. Only through the preparation of such tabular summaries can the total "picture" of all quality checks be seen. These tabular summaries would consolidate all quality checks in one place, including the quality assurance provisions listed in all the Test Procedures contained in Volume II of this report.

As previously mentioned, the development of standard forms, graphs, checksheets, etc., are necessary in a Quality Assurance System for ensuring the completeness and traceability of data and information, for facilitating validation and audit and for a systematic flow of information throughout the system.

In addition to simply recording and calculating data obtained in the performance of a test, other items of documentation are required for building reliability into the system, such as:

- Recording inspection and check results
- Recording calibration results
- Recording preventive maintenance actions
- Reporting unacceptable results

Table 5-1. EXAMPLE OF QUALITY PLAN ACTIVITY MATRIX
PROCUREMENT (RECEIVING - FUELS)

ITEM/CHARACTERISTICS	ACCEPTABLE LIMITS	FREQUENCY OF CHECK	METHOD	CORRECTIVE ACTION	RECORD/ REPORT
F-1. Diesel Fuel Type 1-D					
o Flash Point	120± 2°F	Each Batch	ASTM-D-93	Reject Batch	Receiving Report
o Distillation Range	IBP °F 330-390 10% 370-430 50% 410-480 90% 460-520 EP 500-560	Each Batch	ASTM-D-86	Reject Batch	Receiving Report
o Vendor Batch Analysis	Octane 48-54 Gravity 40-44° API Total Sulphur 0.05-0.20% HC Comp. Arom. 8-15% Viscosity 1.6-2.0	Each Batch	Analysis by Supplier Accompanies Shipper	Reject Batch	Receiving Report

- o Reporting failures
- o Initiating and assuring closed-loop corrective actions
- o Recording audit results
- o Initiating procedural or equipment change notices

It is important that a form developed to accomplish a certain quality function be carefully designed and be self-sufficient. Management should not allow a quality system to dead-end due to an incomplete system of follow-up and distribution of the forms. The following discussion and sample forms pertain to typical forms used in a quality system. These were designed as guidelines and may not satisfy all of an individual laboratory's requirement. A matrix of all forms exhibited in Volume I and their location within the report is shown in Table 5-3.

5.2.1 Recording Inspection Results

When recording inspection results it is important to record the results, when the inspection was performed, how it was performed and whether the test had an acceptable level of performance. Many of the Quality Control checks performed in conducting an emission test are recorded as part of the test data and do not require separate forms, but they need to be identified as quality checks. However, other inspections and checks not directly performed in conducting a test should be documented on a separate form. As an example of an inspection form, Figure 5-1 shows a typical Receiving Inspection Form. Figure 5-2 outlines the form instructions which usually are printed on the back of the form. In addition to this form a reference matrix document is required, issued by Procurement Control or Quality Engineering, outlining the inspection procedures to be used for checking or inspecting the material. The material purchased should have an identifying code number indicated on the purchase order which corresponds with the item number on the plan activity matrix.

The information contained in these forms should be logged in an information file to establish a history which can be used for statistical analysis such as the construction of control charts, for supplier ratings and other purchase review requirements.

5.2.2 Recording Calibration Results

Documentation of instrument or equipment calibration requires the recording of the calibration data or set point in some chronological form. These calibrations should be performed on a periodic basis and the equipment tagged to indicate the last calibration, status of the instrument, and calibration due date. Different colored tags may be used for example, white for calibration, yellow for instruments with limited use, i.e., if only a single range has been calibrated, and red for inactive instruments which require re-calibration before use. Figure 5-3 shows some examples of calibration tags and a rejection tag; Figure 5-4

Table 5-2. EXAMPLE OF QUALITY PLAN ACTIVITY MATRIX
PROCUREMENT (RECEIVING - GAS MIXTURES)

ITEM/CHARACTERISTICS	ACCEPTABLE LIMITS	FREQUENCY OF CHECK	METHOD	CORRECTIVE ACTION	RECORD/ REPORT
G-1. Span Gas - CO					
o Concentration	±2% of Supplier Analysis Range 3000 ppm 2350-2650 Range 2.5% 2.0-2.4	Each cylinder	NDIR Gas comp	Analysis- relabel cylinder with average of duplicate Analysis Range- Return to Supplier	Receiving Log Failure Report Rejection Report
o Cylinder Leakage	None	Each cylinder	Soap Sol'n valve neck, stem, seat.	Return to supplier	Rejection Report
o Hydrocarbon Content	20 ppm	1 cylinder per order	FID Reference standard	Analyze all cylinders Return to Supplier	Receiving Log Failure Report
o Valve	GGA 350	Each	Visual/ Fitting	Return to Supplier	Rejection Report

Table 5-3. SUMMARY OF FORMS REFERENCED IN VOLUME I

TITLE OF FORM	SECTION REFERENCE
Daily Start-up Checksheet	Section 4, Figure 4-1
Preventive Maintenance Checklist, Smokemeter, 6 months	Section 4, Figure 4-2
Preventive Maintenance Checklist, Monthly Inlet Air/Exhaust Measurement System	Section 4, Figure 4-3
Preventive Maintenance Checklist, Analysis System, Monthly	Section 4, Figure 4-5
Preventive Maintenance Checklist, Dynamometer, Monthly	Section 4, Figure 4-6
Preventive Maintenance Checklist, Individual Instruments, Monthly	Section 4, Figure 4-7
Maintenance Log Form	Section 4, Figure 4-8
Receiving Inspection Report	Section 5, Figure 5-1
Calibration Tags	Section 5, Figure 5-3
Calibration Control Punch Card	Section 5, Figure 5-4
Calibration History Evaluation	Section 5, Figure 5-5
Analyzer Curve Generation Data	Section 5, Figure 5-6
Monthly Dyno Calibration Log	Section 5, Figure 5-7
Gas Analysis Report	Section 5, Figure 5-8
Equipment Repair Authorization	Section 5, Figure 5-9
Rejection Report	Section 5, Figure 5-10
Failure Analysis Report	Section 5, Figure 5-11
Corrective Action Request	Section 5, Figure 5-12
Performance Audit Summary Sheet	Section 5, Figure 5-14
Procedure/Equipment Configuration Change Notice	Section 5, Figure 5-15

RECEIVING INSPECTION REPORT

DATE ________________ INVOICE NO. ________________

1. Received From ________________________________

2. Delivered By ________________________________
3. Shipping Damage ________________________________

4. Received By ________________________________
5. No. Pkg./Weight ________________________________
6. PARTIAL ☐ COMPLETE ☐

7. Purchase Order No. ____________ 8. For Department ____________
9. Shipped to Attention of ________________________________
10. Packing Slip No. ____________ 11. Unpacked By ____________
12. Invoice – Packing Slip – Purchase Order checked for correct count and Material Part No. ____________
13. Final inspection to be completed by ____________
14. Sent for final inspection Date ____________

MATERIAL INSPECTION REPORT

15. Inspected By ____________ Dept. ____________
16. Q.C. Inspection Plan ____________ Procedure No. ____________

17. Characteristics Checked	Acceptable Quality Level	Actual Measured Conformance

18. Disposition of Material: ACCEPTED ☐ SEND TO USER ☐
HOLD FOR ORDER COMPLETION ☐ SEND TO STORES ☐ REJECTED ☐
Reason ________________________ Rej. Report No. ______

Distribution: 1. Purchasing 2. Requestor 3. Receiving File
4. Procurement Control

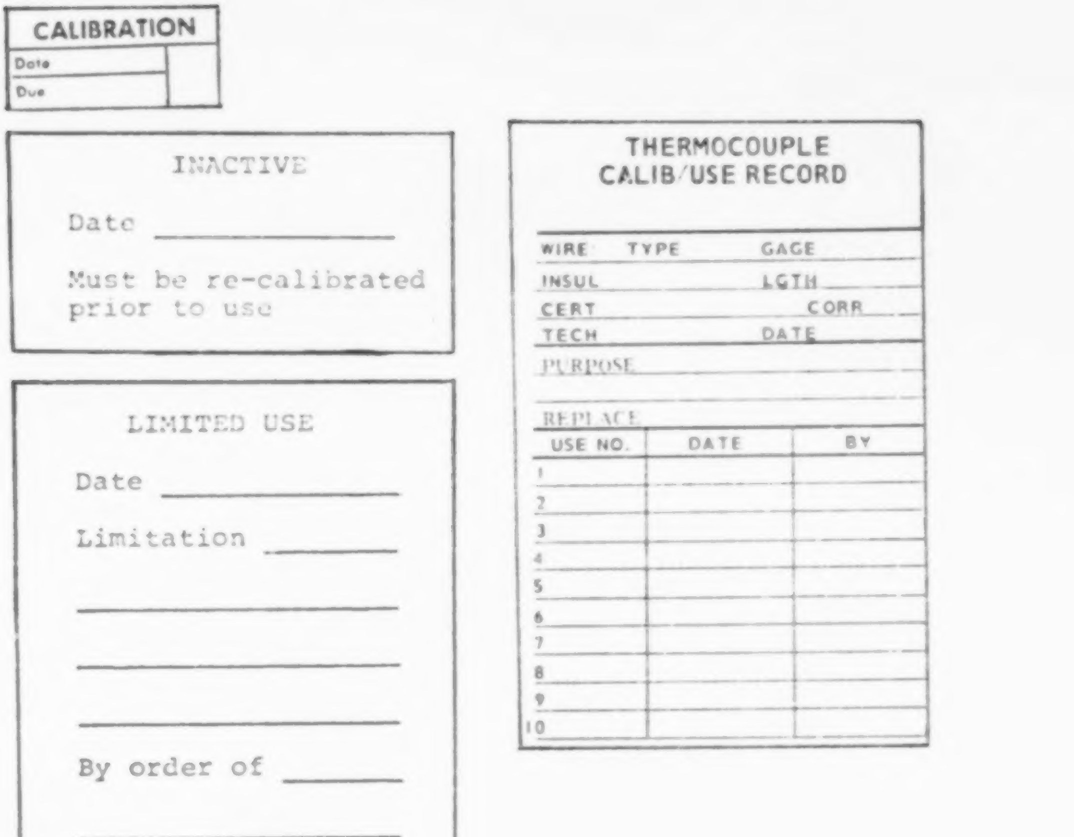
Figure 5-1

Instruction for Receiving Inspection Report

(Printed on back of receiving inspection report)

1. Print name of supplier and address of shipping point.
2. Method of shipment and name of carrier.
3. Record damage to shipping container or any other visual damage observed.
4. Signature of receiver.
5. Record number of packages and total weight.
6. Check one.
7. Record purchase order number, if not available notify purchasing.
8. Department originating order.
9. Department or person requesting material.
10. File packing slip with receiving copy.
11. Person unpacking crate.
12. Compare documents for correct count and part numbers and other information on purchase order. Record discrepancies and report to purchasing and procurement control.
13. Division or group responsible for receiving inspection. Determine from purchase order.
14. Date sent to inspector.
15. Name and department of inspector.
16. File reference for quality planning procedure to be used (see Figure 5-3). Numbers should appear on purchase order. Inspection procedure reference is contained in inspection procedure manual.
17. Characteristic and AQL recorded and results recorded.
18. Check appropriate boxes and give reason for rejected material, and rejection report number, if applicable.

Figure 5-2



CALIBRATION

Date
Due

INACTIVE

Date ______________

Must be re-calibrated prior to use

LIMITED USE

Date ______________

Limitation ________

____

____

____

By order of ______

____

Expires __________

THERMOCOUPLE CALIB/USE RECORD

WIRE TYPE GAGE
INSUL LGTH
CERT CORR
TECH DATE
PURPOSE
REPLACE

USE NO.	DATE	BY
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

GAGE AND INSTRUMENT REJECTION TAG

No. 06738

GAGE OR INSTRUMENT NOMENCLATURE	IDENTIFICATION NO.

MANUFACTURER	MODEL

REJECTED BY	DATE	ORGN. REJ. FROM

REASON FOR REJECTION

Figure 5-3 CALIBRATION TAGS

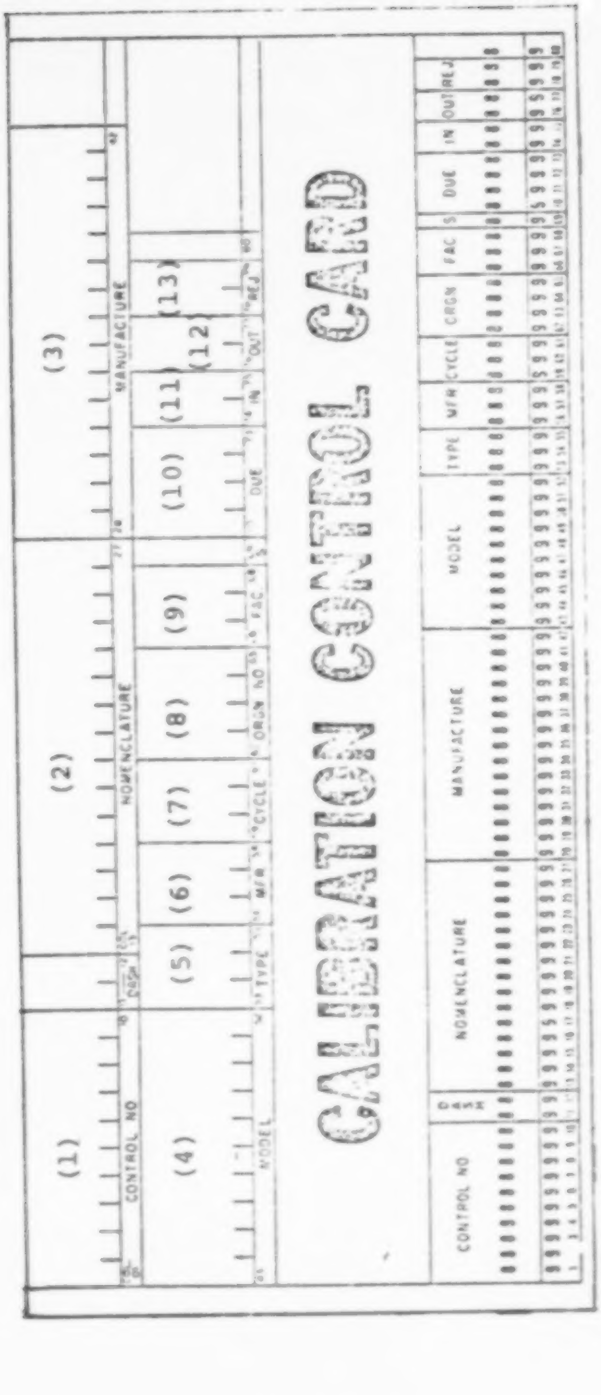

(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
CONTROL NO
NOMENCLATURE
MANUFACTURE
MODEL
TYPE
MFR
CYCLE
ORGN NO
FAC
DUE
IN
OUT
REJ
CALIBRATION CONTROL CARD
DASH
ORGN
S

Figure 5-4 CALIBRATION CONTROL PUNCH CARD

shows a calibration control card. These cards can be processed by the computer to show that periodic calibration has been done. Each time the calibration is performed a new card is issued showing the next due date and remains with the instrument. This eliminates the need for manual audit.

Figure 5-5 is an example of a calibration history evaluation. The time in test, and out of test and number of failures are recorded for evaluation purposes. This type of form could also be used to record daily checks in the instrument log books. These records could be collected and evaluated periodically for such things as indication of trends/plotting of control charts or cost evaluation studies.

Of primary concern in the measurement system is the calibration of the analytical instruments, dynamometer and the gas mixtures. The smokemeter calibration is performed daily on each test and the daily start-up sheet is used for documentation (Figure 4-1). Procedures for calibrating these items have been detailed in Volume II of this report. Examples of forms presently in use are given in Figures 5-6, 5-7, and 5- These forms are used to record raw data only. The data output from this data is usually audited manually or automatically, depending on the program used to reduce the data, to locate points which may be out of tolerance, curve slope changes and other types of errors. The raw data should always be maintained in the instrument log book.

5.2.3 Recording Maintenance Actions

Preventive maintenance actions are performed on a periodic routine schedule as outlined by the preventive maintenance guidelines, discussed in Section 4, and chronologically recorded in the instrument or test cell maintenance log book. A typical Maintenance Report format is illustrated in Figure 4-8. Audit of this log book by quality assurance usually will be sufficient to assure that the maintenance is done. Entries in the log book should be signed by the person performing the maintenance.

Non-routine maintenance performed because of an equipment failure can supply meaningful information to facility management. Frequently, for the sake of expediency, the maintenance is performed but never reported through the proper channels. Reporting of all failures should be mandatory as this information is invaluable in determining equipment reliability and cost. In addition, frequent failures of certain equipment will indicate a need for corrective action. One method of recording these failures is through a work order or equipment repair authorization form. The work order should be issued by production control and summarized in a weekly report. Copies of the completed work order should be filed in the equipment records file. A typical work order request is presented in Figure 5-9.

CALIBRATION HISTORY EVALUATION

EQUIP TYPE ______________________________

MFR. ______________________________

MODEL ______________________________

EVALUATED BY ______________________________

TIMES FAIL ______________

DATE ______________

TIMES CAL. ______________

TIMES O.T. ______________

% O.T. ______________ PERCENT

AVG. CAL. TIME ______________ HOURS

CONTROL NO.	I.T.	O.T.	FAIL	REMARKS

Evaluation Summary: ______________________________

Corrective Action ______________________________

By ______________ Date ______________

Follow-up Required ______________________________

Follow-up By: ______________ Date ______________ Remarks ______________

Figure 5-5

TESTING SERVICES DIVISION

ANALYZER CURVE GENERATION DATA

DEPT NO	TRAIN	DATE	P.I.C.

ANALYZER	RANGE	CELL LENGTH	ATTENUATION	NEXT RUN NUMBER

CYLINDER NO	DEFLECTION	CONCENTRATION	FLOW RATE	NO.

☐ ZERO GAS ☐ AIR ☐ NITROGEN ☐ NEW ☐ UPDATE

COMMENTS:

Figure 5-6

MONTHLY DYNAMOMETER CALIBRATION LOG

Cell No.__________ Model No.__________ Serial No.__________

H.P. Max.______ Calibrated By__________ Supv.__________ Date________

A. RPM

Output______________

Calib. Equip. Type______________

Control Number______________

	0	500	1,000	1,500	2,000*	2,500
Before Adjustment						
After Adjustment						

*Adjustment Point

Computer Input Alignment Checked ☐ Failure Report Required ☐

Comment: ______________________________________

____

B. TORQUE

Output______________

Weights I.D.______________

Torque Arm Length______________

Dyno. Constant______________

Before Adjustment Zero = __________ Max. = __________

After Final Adjustment Zero = __________ Max. = __________

TORQUE CALIBRATION

	WEIGHT ADDED	TORQUE CALCULATION WEIGHT x LENGTH	TORQUE ACTUAL
1	0	0	
2			
3			
4			
5			
6			
7			
8			
9			
10			

Computer Input Alignment Checked ☐ Failure Report Required ☐

Maintenance Performed ☐

Comment: ______________________________________

____

Figure 5-7

Figure 5-8

GAS ANALYSIS REPORT

CYLINDER #	MIXTURE REQUESTED	ANALYSIS

Supplier ____________________ Analyst ____

Requestor ____________________ Date ________________________________

____________________ P.O.# ____________________________

No. of Cylinders in order _____ Project # ________________________

Invoice # ________________________

____

Report Data To ____

Comments ____

____

Figure 5-9

Equipment Repair Authorization

Job # ____________

REQUEST

Name ______________________________ Date Submitted ____________
Branch ______________ Section ______________ Extension ____________
Equipment I.D. Number ______________________________
Job Description (Attach sketches needed) ______________________________

Special Equipment Required ______________________________
Proprietory Item: ☐ Yes ☐ No
Craft Requested ______________________________
Date Item To Be Delivered for Test ______________________________
Latest Acceptable Completion Date ______________________________

SCHEDULE - Equipment Maintenance

Date Request Rec'd ______________
Craft(s)/Team Assigned ______________

Date ________ Time ________ am/pm
Equipment Back On Line
Date ________ Time ________ am/pm
Equipment Repaired ______
Replaced ______

Equipment Repair Service Contacted
Date ________ Time ________ am/pm
Authorized by ______________

Total Down Time ______________
No. of Test Rescheduled ______________
Test Supervisor ______________

Equipment Maintenance Report

Technician ______________
Date Began ________ Time ________ am/pm
Date Complete ________ Time ________ am/pm
Man-Hours ______________
Parts Replaced ______________

Comments ______________

Repair Service Report

Date Began ________ Time ________ am/pm
Date Complete ________ Time ________ am/pm
Man-Hours ______________
Parts Replaced ______________

Comments ______________

Service Charges ______________

WHITE: REQUESTOR'S COPY
YELLOW: PRODUCTION CONTROLLER'S COPY
PINK: LAB SECTION CHIEF'S COPY
GOLD: REQUESTOR'S IN-PROCESS COPY

Equipment repair may be performed in-house or by outside servicemen. In either case the same job request form should be used and completed indicating the service performed, man hours and parts replaced. In addition the total charge for the service performed should be noted.

5.2.4 Reporting Unacceptable Results

Quality assurance has the responsibility for identifying areas of the measurement system which need special consideration in order to reduce the cost of the measurements, to increase production and improve reliability. One useful tool in determining these areas is an adequate system for reporting unacceptable results. These results should not be limited to the tests rejected by data validation but should include any determination made in the measurement system such as receiving inspections, equipment calibrations, test engine inspections, test cell correlations and other auxiliary laboratory tests. A typical Rejection Report for use in reporting unacceptable results is shown in Figure 5-10. This report should contain the type of result such as void test, the unacceptable characteristic or data such as torque-RPM trace error, the reason for rejections and any immediate corrective action taken. The specific cause of the unacceptable results should be clearly identified.

Analytical summaries of these rejection reports should be prepared and reported to management by quality assurance. Monthly and yearly summaries by categories are quite helpful in identifying problem areas and projecting realistic schedules. Areas requiring corrective action may be identified and reliability of equipment and personnel can be objectively assessed from the information contained in these summary reports.

5.2.5 Failure Reporting and Analysis

A failure can be defined as the inability of a piece of equipment or an engine to perform within previously specified limits.

Failure rates can be reduced in magnitude with a resulting reduction in testing costs if the following ground rule is applied. Equipment, engines and instruments which have exhibited a trouble or failure, continuing or intermittent, shall not be re-used or repaired until such time as the trouble is isolated, the cause clearly established and corrective measures investigated, approved and taken to assure that the probability of recurrence is minimized.

The documentation of failures and the ensuing failure analysis provides essential data for investigating the cause of failure and the initiation of corrective action to preclude future recurrence. A typical Failure Analysis Report is shown in Figure 5-11.

REJECTION REPORT NO.

PART NUMBER	PART NAME		SUPPLIER/MFR
REJECTED QUANTITY / DATE	CONTRACT	PURCHASE ORDER NO.	REC. REPORT NO.

ITEM NO.	DISCREPANCIES

REJECTED BY	DATE	SUPERVISOR APPROVAL DATE	Q.A. APPROVAL DATE

DISPOSITION

USE AS IS ☐

RETURN TO SUPPLIER ☐

OTHER (SPECIFY)

☐ CHECK IF FAILURE ANALYSIS REQUIRED

FAILURE ANALYSIS REPORT NO. ____________

CORRECTIVE ACTION

Q.A. APPROVAL ________ DATE ________

Figure 5-10

COMPLETED BY OPERATOR/ANALYST

INSPECTOR ____________
REPORT NUMBER ____________

DATE ____________

FAILURE ANALYSIS REPORT

EQUIPMENT TYPE	MANUFACTURER	MOD. NO.	SER. NO.
NO. OF PAST FAILURE REPORTS	DATE-LAST FAILURE	HOURS SINCE LAST LOCATION FAILURE	
ESTIMATED CAUSE DETERMINATION	EXPECTED, RANDOM	ASSIGNMENT CAUSE	REQUIRES LAB INVESTIGATION
	CAUSE DETERMINED OR TYPE INVESTIGATION NEEDED		

COMPLETED BY LABORATORY

TESTS PERFORMED: ____________

FAILURE CAUSED BY: ____________

DISPOSITION: ☐ REPAIR ☐ SCRAP ☐ REPLACE ☐ OTHER ☐ RETURN TO MANUFACTURER

RECOMMENDED CORRECTIVE ACTION TO PREVENT RECURRENCE

ACTION COPIES TO: ____________

RECOMMENDED BY ____________ REVIEWED BY ____________

COMPLETED BY PROJECT OFFICER

CORRECTIVE ACTION TAKEN ____________

RESULTS AND RECOMMENDATIONS ____________

APPROVED ____________ DATE ____________

CLOSED OUT ____________ DATE ____________

Figure 5-11 FAILURE ANALYSIS REPORT

The technique of Pareto analysis can be utilized very effectively in analyzing failure types, as the bulk of failures, downtime, etc., are traceable to a vital few failure modes. Basically, the Pareto analysis attempts to find the maldistribution for which the fewest potential failure modes provide the greatest potential for corrective action applications. This technique is discussed in Reference 5-1.

5.2.6 Initiating and Assuring Closed-Loop Corrective Action

Corrective actions are of two kinds. The more frequently encountered type is immediate or on-the-spot corrective action to correct non-conforming data or equipment. It is important in this case to differentiate between normal non-reportable procedural adjustments of equipment that are performed as a matter of course during a test due to the characteristic of the equipment, and those adjustments that are performed in actual out-of-control situations, which should be reported as unacceptable results (section 5.2.4).

The second kind, long term corrective action, is invoked when it becomes necessary to identify and eliminate the cause of non-conformance and to prevent, if possible, the reoccurrence of the out-of-control condition. It is important that once a condition of unacceptable quality is detected, a systematic and timely mechanism is established to assure that the condition is reported to those assigned responsibility for correction of the condition. A positive closed loop mechanism must be established to assure appropriate corrective action is taken.

Documentation of closed loop corrective action usually takes the form of the corrective action request. A request for corrective action can be initiated by anyone in the system, however, the formal request is the responsibility of Quality Assurance management and is usually assigned as a function of quality engineering. A typical corrective action request form is presented in Figure 5-12.

To illustrate the use of a corrective action request form, assume a test operator has observed that a CO Analyzer valve malfunctioned. The flow chart illustrated in Figure 5-13 traces the various steps and interactions required to process a corrective action request.

Generally, it is the responsibility of quality assurance to utilize whatever means are available to see that the necessary actions are completed. Sometimes corrective action coordination responsibility is assigned to an engineering function, with quality assurance monitoring the effectiveness of the system. Weekly status reports to management of each of the assigned actions is usually adequate. If the action is not completed by the required date, quality assurance/engineering should follow up, requesting an interim report of the progress and reasons for the incompletion. If the responsible organization is unable to meet the deadline it should request an extension and any additional information or assistance required for completion of the action.

Corrective Action Request

REQUESTOR

1. Request initiated by ______________________ Dept. ______________

Date ______________________ Authorization ______________________

2. Brief description of non-conformance ______________________

____

____

____

3. Recommended Action ______________________________

____

____

QUALITY ENGINEERING

4. Assigned to ______________ Date __________ File No. ________

5. Quality Analysis (Attach complete report if necessary)

____

____

____

____

6. Action Required ______________________________

____

____

____

7. Action to be initiated by ______________________________

Expected Completion Date ______________________________

Follow-Up Date ______________ Action Completed Yes No

RESPONSIBLE DEPARTMENT

8. Action Assigned To ______________ Date ______________

Completion Date ______________ Supervisor ______________

Special Instructions ______________________________

____

____

9. Action Completed - Date ______________ Time ______________

Quality Engineering Notified ______________________________

Requestor Notified ______________________________

10. Comments ______________________________

____

Figure 5-12

CORRECTIVE ACTION REQUEST - FLOW CHART

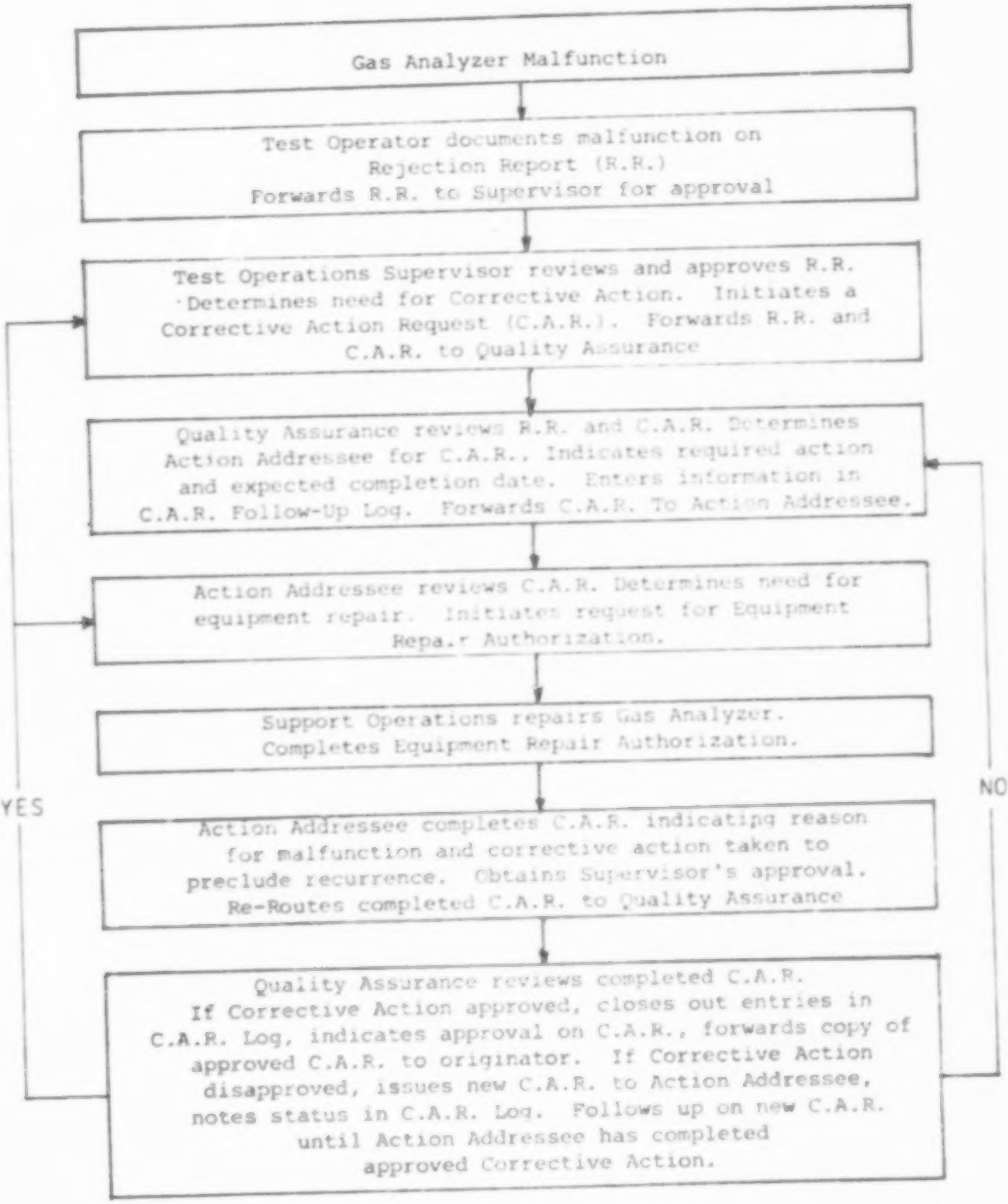

Gas Analyzer Malfunction
Test Operator documents malfunction on Rejection Report (R.R.) Forwards R.R. to Supervisor for approval
Test Operations Supervisor reviews and approves R.R. Determines need for Corrective Action. Initiates a Corrective Action Request (C.A.R.). Forwards R.R. and C.A.R. to Quality Assurance
Quality Assurance reviews R.R. and C.A.R. Determines Action Addressee for C.A.R.. Indicates required action and expected completion date. Enters information in C.A.R. Follow-Up Log. Forwards C.A.R. To Action Addressee.
Action Addressee reviews C.A.R. Determines need for equipment repair. Initiates request for Equipment Repair Authorization.
Support Operations repairs Gas Analyzer. Completes Equipment Repair Authorization.
Action Addressee completes C.A.R. indicating reason for malfunction and corrective action taken to preclude recurrence. Obtains Supervisor's approval. Re-Routes completed C.A.R. to Quality Assurance
Quality Assurance reviews completed C.A.R. If Corrective Action approved, closes out entries in C.A.R. Log, indicates approval on C.A.R., forwards copy of approved C.A.R. to originator. If Corrective Action disapproved, issues new C.A.R. to Action Addressee, notes status in C.A.R. Log. Follows up on new C.A.R. until Action Addressee has completed approved Corrective Action.
YES
NO

FIGURE 5-13

Upon completion of the action, management, the Quality Engineering Supervisor and the person or department initiating the request should be notified.

In the interest of saving time and getting the job done the communication of the problems and progress should be done verbally by the Quality Engineering Supervisor, handwritten notes to the file would normally be sufficient for extensions and other analysis or agreements made. Quality assurance should review all open files.

5.2.7 Recording Audit Results

There are two types of audit discussed in this report, independent performance audits and quality assurance system surveys. The procedure and types of documentation required for a quality assurance system survey are outlined in Section 8 of this report.

The documentation used in recording the results of independent performance audits would essentially be the same data collection forms as are normally used in the collection of that particular data. In addition to these data records, control charts may be subsequently plotted using the audit results to determine if the element being audited is performing within established limits. Control chart techniques are discussed in detail in Section 6.

A performance audit summary sheet should be maintained by the auditor to provide a history of audits performed (Figure 5-14). Periodic review of this summary will indicate whether the original audit schedule is effective or if a tightened or reduced schedule is required. Separate summary sheets should be prepared for each of the major elements audited, i.e., Instrumentation, Operator, Sampling System and Data Processing.

5.2.8 Initiating Procedural or Equipment Change Notices

A clearly defined system is characteristic of a good quality system. However, it must be responsive to changes resulting from advances in the state-of-the-art in the measurement system. Any change effective on a temporary basis or for a particular series of tests must be systematically documented to reflect evidence of such a change in subsequent analysis of the data.

Changes in the design of the equipment used in the measurement system must also be carefully documented. Configuration control of the total test system is important since not only do the basic sample handling procedures change but actually instrumented analyses change with results that are not directly correlatable. In many cases, changes should not be made until a comparative analysis has been completed in order to assure that the recommended changes do not affect accuracy and precision in a deleterious way. For example, hydrocarbons may be measured by non-dispersive infrared (NDIR) by flame ionization (FID) or by an FID with a heated sampling system.

PERFORMANCE AUDIT SUMMARY SHEET

AUDIT ELEMENT: ☐ INSTRUMENTATION ☐ OPERATOR ☐ SAMPLING SYSTEM ☐ DATA PROCESSING

AUDIT DATE	TYPE OF AUDIT	AUDIT RESULT			AUDITED BY
		ACC.	UNACC.	CORRECTIVE ACTION TAKEN	

FIGURE 5-14

The numbers are only significant for those emission standards based on the particular method of analysis. NDIR hydrocarbon measurements are of little use in the 1975 heavy duty diesel procedure but are required by the 1975 heavy duty gasoline engine procedure.

The responsibility for procedural change and equipment configuration control should be assigned by management policy. Quality Assurance has responsibility for approval of all changes. Distribution of the changes is usually performed by those with responsibility for manual control. All affected individuals should be informed of the changes on a timely and formal basis.

An example of a document used to effect configuration and procedural changes in the measurement system is given in Figure 5-15. A similar document could be used to effectively control changes in computer programs in facilities which employ computer systems for testing and computational services. Procedures for document control are given in Appendix C of this report.

Figure 5-15

PROCEDURE/EQUIPMENT CONFIGURATION CHANGE NOTICE

1. ORIGINATOR: ______________________ 2. DATE: ______________

3. TYPE OF CHANGE: EQUIPMENT ☐ PROCEDURE ☐

4. REFERENCE DOCUMENT: ______________________________________

5. CHANGE REQUESTED BY: ______________________________________

6. PURPOSE OF CHANGE: ______________________________________

____

____

7. DESCRIPTION OF CHANGE: (Attach Details, Specifications or Drawings if Necessary).

____

____

____

____

8. EFFECTIVITY: ______________________________________

9. DURATION OR EXTENT OF USE: ____________ TEMPORARY ☐ PERMANENT ☐

10. AREAS AFFECTED: LDT ☐ E&D ☐ CHEM ☐ LAB ☐

HDT ☐ I&E ☐ C&M ☐ DATA ☐

OTHER

11.	APPROVALS REQUIRED	YES	NO	DATE
ECTD				
OPM				
CSD				

(If not approved please discuss reasons on reverse side)

12. RETURN TO ORIGINATOR FOR DISTRIBUTION TO REVIEWERS AND AREAS AFFECTED.

Section 6

APPLICATION OF STATISTICAL QUALITY ASSURANCE METHODS TO THE EMISSION TEST SYSTEM

An effective and efficient quality assurance system requires the appropriate use of statistical methods. The nature of the data collected from the system requires the use of some specific statistical methods, although practically all statistical tools can be applied to quality assurance data at one time or another.

6.1 STATISTICAL METHODS

Several of the most useful applications of statistical methods as they apply to mobile source emission testing are as follows:

1. Use of statistical control charts for:
    - a. Successive zero/span checks
    - b. Constants of calibration curve solutions
    - c. Agreement between duplicate checks
    - d. Differences between original and independent audit checks
    - e. Flow rate calibration checks
2. Regression analysis for:
    - a. Calculation of calibration curves
    - b. Determining relationships between variables in measurements
3. Statistical sampling plans for:
    - a. Inspection of procured materials
    - b. Determining frequency of checks using standards, and duplicate checks
    - c. Determining frequency of zero/span checks
    - d. Determining frequency of multipoint calibrations

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4. Analysis of distributions of data to measure the inherent variability in the data, and to establish limits of agreement for duplicate checks, independent performance audit checks, and other distributions for which control chart limits need to be established

5. Analysis of failure rates to determine optimum frequencies for preventive maintenance and scheduled replacement of components

6. Use of probability paper to make predictions based on a normal distribution.

6.1.1 Special Applications of Statistical Methods

There are specialized statistical techniques which can be used as effective tools in analyzing variables. The analysis of variance can be used for performing special comparisons of variables in the measurement system. Statistical designs for planning special studies to determine effects of suspected variables can be developed, and are particularly useful in investigation of possible causes of quality problems.

6.1.2 Statistical Techniques and Nomenclature

Certain methods almost always constitute, in part, a good quality assurance system. Subsequently, an understanding of certain fundamental statistical techniques and nomenclature is necessary in establishing proper quality assurance procedures. Appendix A-1 provides a glossary of such terms.

6.2 CONTROL CHARTS

This section describes the definition, purpose, format and application of control charts as they apply to mobile source emission testing.

6.2.1 Definition and Purpose of Control Charts

A control chart is a chronological graphic comparison of mobile source emission testing data to computed control limits that are drawn as limit lines on the chart. The primary purpose of the control chart is to identify specific causes of variation. Variation can be attributed to two causes, assignable, i.e., as a result of "findable," and random, i.e., small, nontraceable, "chance" factors. The role of the control chart is concerned with assignable causes.

The control chart presentation of quality is helpful for many reasons; among them are:

- o Detection of trends which could lead to "out-of-control" conditions, or create problems if not corrected at time of detection.
- o Visual record assuring completion of routine checks.
- o Levels of quality can be more readily prescribed based on observed, obtainable, past levels.
- o Management decision-making can be more readily based on easy access to past quality data.
- o A "picture" of quality as exemplified in quality charts is the single best description of performance.

6.2.2 Format

The format of the control chart usually follows the configuration presented in Figure 6-1. The upper and lower control limits define the expected spread. Plotting a central line delineating the average level of the values is helpful in evaluating biasing, and detecting trends.

6.2.3 Types of Control Charts

In Appendix A-1 the concepts of precision and accuracy are defined. Generally, precision is the ability of a system to reproduce its own levels of performance. Accuracy is the difference between a measurement and a true value. Precision control charts delineate the amount of variability among replicate laboratory analyses results. Variability can be expressed in the unit of measurement of the variable or in terms of percent. When the extent of variability is a function of the level of gas concentration, then the Coefficient of Variation (CV) or Relative Range (%R) control charts are appropriate. Control charts indicating levels of accuracy can also be constructed. The standard deviation or range defined in terms of physical units is a convenient method for measuring the variability among accuracy determination data. A detailed discussion of types of control charts is contained in Appendix H of Reference 6-1.

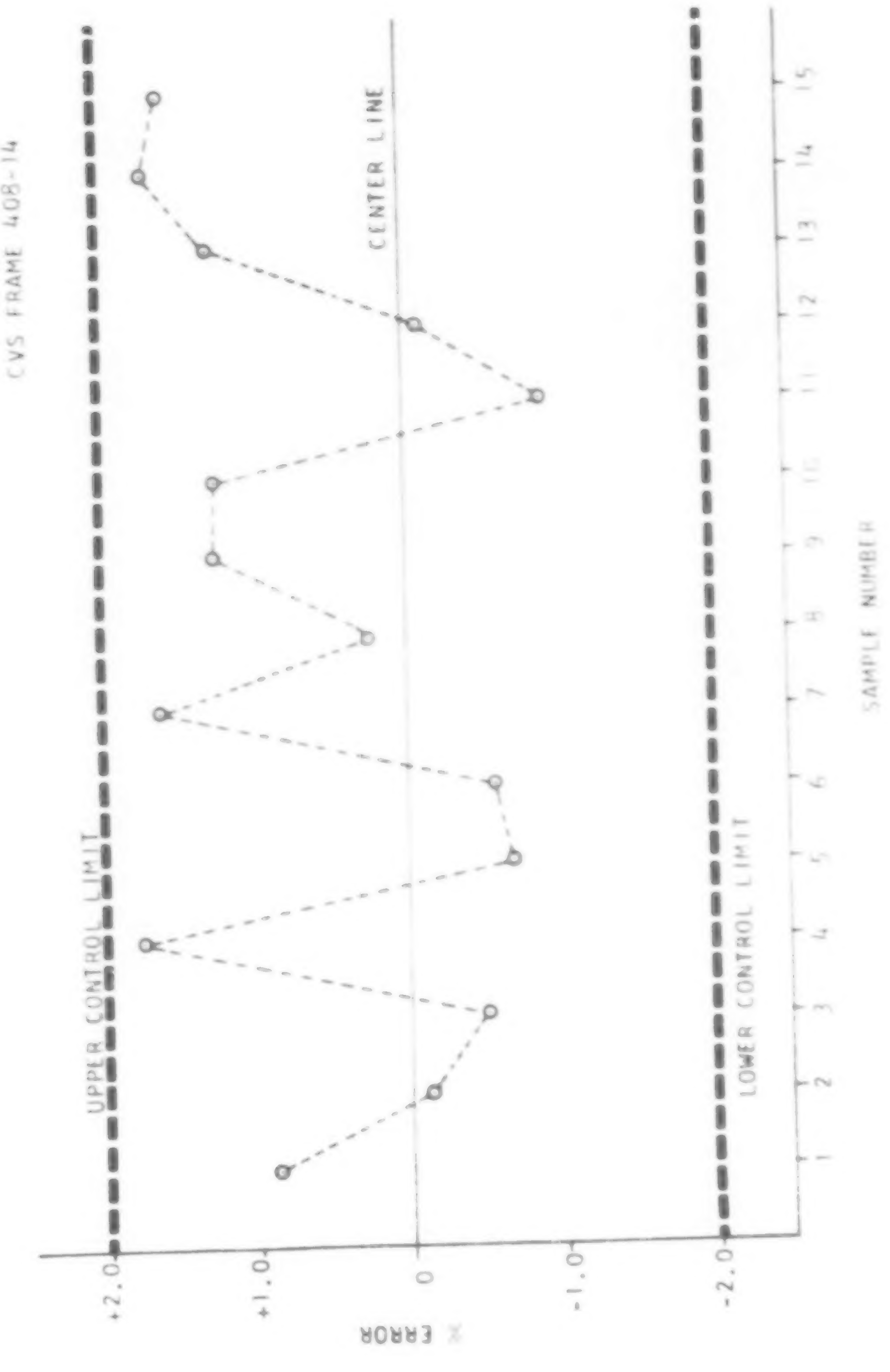


Figure 6-1. PROPANE INJECTION TEST — % ERROR

6.2.4 Applications of Control Charts in Mobile Source Emission Testing

In mobile source emission testing, control chart techniques are implemented to determine whether the errors associated with the analytical data are within operational limits designated for the method. For example, the precision of an exhaust emission meaurement system can be evaluated from the use of replicate analysis results. This can be accomplished by performing replicate measurements using known HC, CO, CO_2, and/or NO_x concentrations and monitoring the degree of variability among the replicates. Other methods of replicate analysis include the retesting of gas in a bag, and the use of a correlation vehicle.

Some typical applications of control charts in 1975 FTP testing situations are summarized in Table 6-1. Construction of these various types of charts is discussed in the following sections.

6.2.5 Precision Control Charts

In using control charts, precision can be expressed in the unit of measurement of the variable or in percent. When expressing precision in terms of units, variations can be expressed as a range, using R-Charts, or as standard deviation using s-charts. In air pollution study applications, precision is often computed in terms of a percent using the relative range (%R) chart or the coefficient of variation (CV) chart.

The following nomenclature should be noted:

$$R = \text{Maximum} - \text{Minimum}$$

$$s = \left(\frac{\sum (x-\bar{x})^2}{n-1}\right)^{0.5}$$

$$\%R = \frac{R}{\bar{x}} \times 100\%$$

$$CV = \frac{s}{\bar{x}} (100)\%$$

Table 6-1. APPLICATIONS OF STATISTICAL CONTROL CHARTS IN 1975 FTP TESTING

TYPE OF CONTROL CHART	APPLICATION	AREAS OF APPLICATION WITHIN MOBILE SOURCE EMISSION TEST PROCEDURES
Coefficient of variation control charts	Monitoring precision of positive displacement pump by maintaining control charts on various parameters	CVS calibration procedures for positive displacement pump
Range chart	Measurement of recorder chart speed	Chart recorder calibration
Signed difference chart Relative Range, CV charts	Difference in coastdown time Precision of speedometer, power meter	Dynamometer calibration
Relative Range, CV charts	Determining precision of gas mixture	Gas Mixture calibration
Percent error Signed difference chart Relative Range, CV charts	Propane injection test Correlation Vehicle Retest of Gas Bag	CVS accuracy checks
Mean and Range charts	Measure variation in gain, zero, P, etc.	Daily Start-Up checks
Percent defective charts	Monitoring rejection rate of test data entries.	Data Validation tests

Where:

R = Range

s = Standard Deviation

%R = Relative Range

CV = Coefficient of Variation

x = Individual Value

$\bar{x}$ = Mean Value

n = Number of Replicates

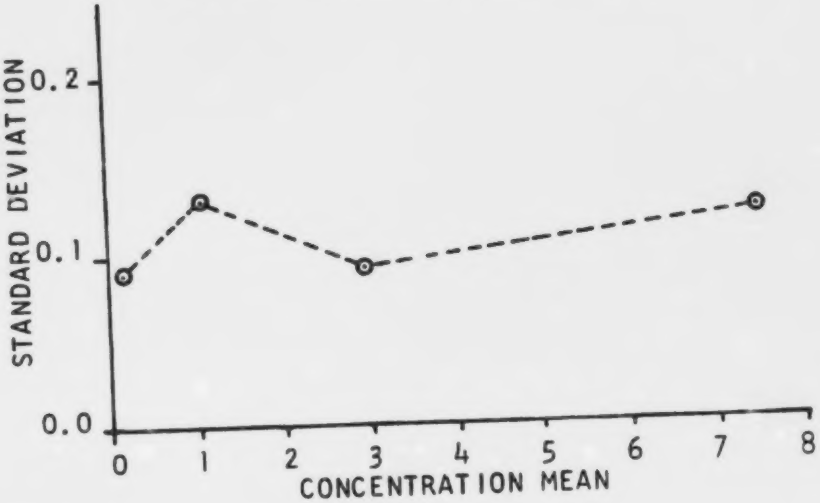
Replicate analyses should be made on known standards at different levels and evaluated to determine the type of precision control charts to use. Standards should be used which represent the high and low and at least one, however preferably two, intermediate concentrations encountered during testing. Between five and ten replicate analyses should be made for each known concentration.

The mean ($\bar{x}$) and standard deviation (s) for each concentration should be found, i.e., calculate $\bar{x}_1$, s_1, $\bar{x}_2$, s_2, $\bar{x}_3$, s_3, $\bar{x}_4$, s_4. Plot these values on a scatter diagram. They will normally coincide with one of the two configurations: (1) the standard deviation is essentially independent of the concentration mean, or (2) the standard deviation is dependent upon changes in concentration. Typical examples of these two configurations are shown in Figure 6-2. The plotted points were obtained from the data compiled in Table 6-2.

The standard deviation (s) or range (R) control chart techniques are applicable if Case 1 exists. Note, however, that in the mobile source emissions testing context R-Charts are normally used, as the range is an efficient estimator of the variation, and the number of replicates do not usually exceed two. CV-Charts or %R-Charts should be implemented if Case 2 occurs.

Relative Range or CV-Charts are derived from measurements obtained from replicate analysis of routine samples. In mobile source emission testing systems it is customary to use two replicates for precision determination and in such situations the use of Relative Range charts is recommended. Where the number of replicates exceed two, the Coefficient of Variation chart is appropriate.

CASE 1 — STANDARD DEVIATION ESSENTIALLY INDEPENDENT OF CONCENTRATION



CASE 2 — STANDARD DEVIATION INCREASES PROPORTIONATELY WITH CONCENTRATION

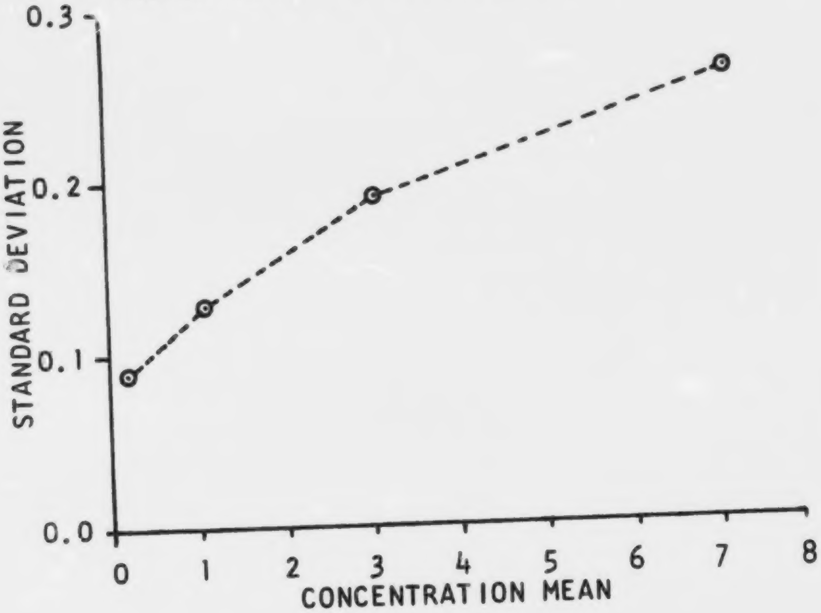


Figure 6-2. SCATTER DIAGRAMS FOR DETERMINING TYPE OF CONTROL CHART

Table 6-2. MEASURED DATA USED IN SCATTER DIAGRAM CONSTRUCTION

CASE 1			CASE 2		
X	$x - \bar{x}$	$(x - \bar{x})^2$	x	$x - \bar{x}$	$(x - \bar{x})^2$
0.2	0	0	0.2	0	0
0.1	-.1	.01	0.1	-.1	.01
0.2	0	0	0.2	0	0
0.3	.1	.01	0.3	.1	.01
0.1	-.1	.01	0.1	-.1	.01
$\bar{x}$ = 0.2		s = .09	$\bar{x}$ = 0.2		s = .09
1.0	-.1	.01	1.0	-.1	.01
1.1	0	0	1.1	0	0
1.2	.1	.01	1.2	.1	.01
0.9	-.2	.04	0.9	-.2	.04
1.2	.1	.01	1.2	.1	.01
$\bar{x}$ = 1.1		s = .13	$\bar{x}$ = 1.1		s = .13
3.0	0	0	3.0	-.1	.01
2.9	-.1	.01	3.1	0	0
3.1	.1	.01	3.3	.2	.04
3.0	0	0	2.8	-.3	.09
2.9	-.1	.01	3.2	.1	.01
$\bar{x}$ = 3.0		s = .09	$\bar{x}$ = 3.1		s = .19
7.4	-.1	.01	7.4	.2	.04
7.5	0	0	7.0	-.2	.04
7.3	-.2	.04	7.5	.3	.09
7.6	.1	.01	6.9	-.3	.09
7.5	0	0	7.1	-.1	.01
$\bar{x}$ = 7.5		s = .12	$\bar{x}$ = 7.2		s = .26

6.2.5.1 Construction of Range Precision Control Charts (R-Charts)

The following procedure should be used to construct a range control chart. A typical example is shown in Figure 6-3. The plotted points were obtained from Table 6-3.

- List the absolute values of the range (R) for each set of replicates (x_1, x_2)
- Compute $\overline{R}$, the average value of R for all sets of replicates using the formula

  $\overline{R} = \frac{R}{N}$ with N = number of sets of replicates

- Compute the upper control limit, UCL, using the formula

  $UCL = D_4\overline{R}$.

  The value of D_4 is obtained from Appendix A-2.

- Compute the lower control limit, LCL, using the formula

  $LCL = D_3\overline{R}$.

  The value of D_3 is obtained from Appendix A-2.

- Draw the line for $\overline{R}$ on the control chart
- Plot the values for ranges of each set of replicates.

For this control chart, the computed control limits are 3σ limits (corresponding to 99.7 percent limits). Consequently, 99.7 percent of the computed range values should be between these control limits, if the system is "in-control." Other confidence intervals could have been implemented. In doing so, the multiplication factors would be different from the ones given in Appendix A-2. Refer to reference 6-2 for the use of other probability limits. Note, however, that 3σ limits are normally recommended for use.

The data plotted on the precision control charts should be approximately evenly distributed about the mean value line. If any result plotted on the control chart falls outside of the established control limits, the system should be deemed "out-of-control" and an investigation initiated to determine necessary corrective action to restore controlled conditions. Where possible, reanalyze all affected samples when an "out-of-control" situation occurs.

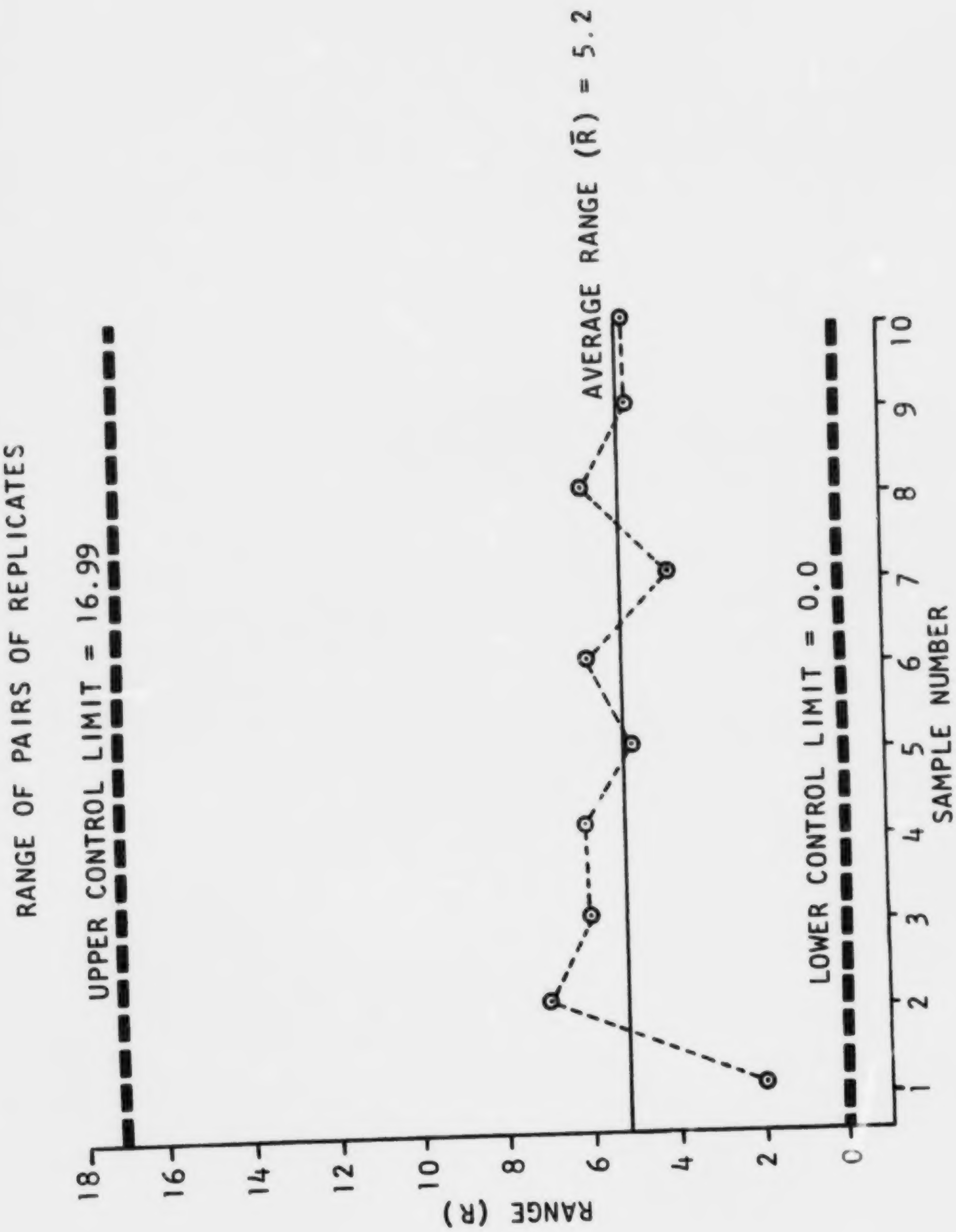


Figure 6-3. RANGE CONTROL CHART

Table 6-3. DATA VALUES AND COMPUTATIONS FOR CONSTRUCTING RANGE CONTROL CHART LIMITS

SAMPLE	x_1	x_2	R
1	10	12	2
2	15	22	7
3	21	15	6
4	11	17	6
5	30	25	5
6	45	51	6
7	50	46	4
8	42	48	6
9	10	15	5
10	21	26	5
			R TOTAL = 52

$$R = \left| x_1 - x_2 \right|$$

$$\overline{R} = \frac{R}{N} = \frac{52}{10} = 5.2$$

$$UCL = D_4 \overline{R} = 3.267 \times 5.2 = 16.99$$

$$LCL = D_3 \overline{R} = 0 \times 5.2 = 0.0$$

D_3 and D_4 are multiplication factors when observations in each subgroup = 2

6.2.5.2 Construction of Relative Range Control Charts

- Calculate the range, R, established by each sampled duplicate set.
- Calculate the arithmetic mean, $\bar{x}$, for each sampled duplicate set.
- For each sampled duplicate set, calculate the relative range using the formula

  $$\%R = \frac{R}{\bar{x}} \times 100\%.$$

- Calculate the average relative range using the formula

  $$\overline{\%R} = \frac{\sum_{j=1}^{N} \%R_j}{N}$$

  where N = Total number of sampled duplicate sets.

- Calculate the lower control limit using the formula

  $$LCL = D_3 \overline{\%R}.$$

  The value of D_3 is obtained from Appendix A-2.

- Calculate the upper control limit using the formula

  $$UCL = D_4 \overline{\%R}.$$

  The value of D_4 is obtained from Appendix A-2.

- Construct the Relative Range Chart delineating the values of $\overline{\%R}$, UCL and LCL.

Figure 6-4 is an example utilizing the above procedure. The hypothetical data used and the necessary calculations are given in Table 6-4.

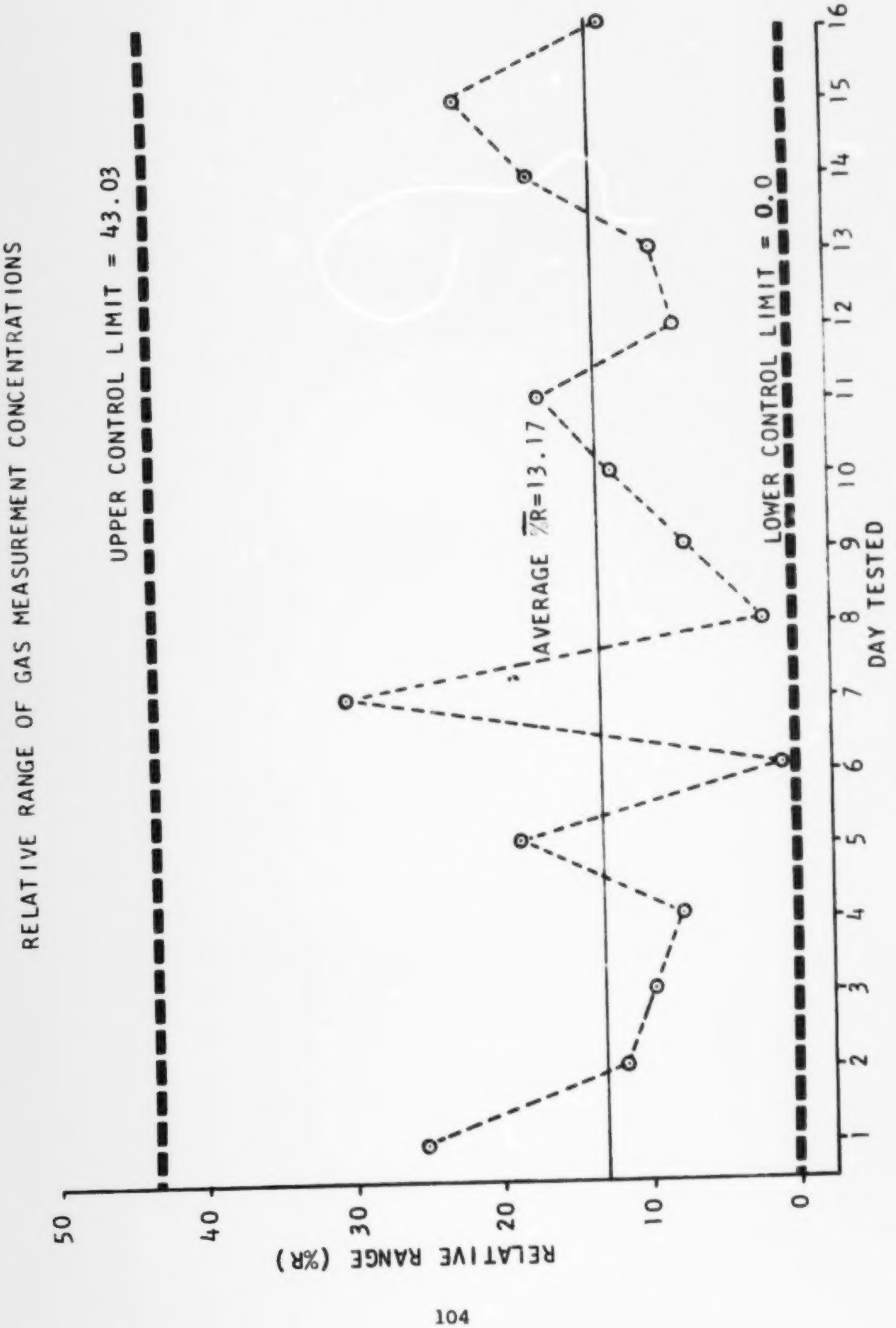


Figure 6-4. RELATIVE RANGE CONTROL CHART

Table 6-4. CONCENTRATION MEASUREMENTS - RELATIVE RANGE CALCULATION

DAY	MEASUREMENTS, PPM		R	$\overline{X}$	%R
	x_1	x_2			
1	29.2	22.7	6.5	25.95	25.05
2	28.4	25.2	3.2	26.80	11.94
3	29.2	26.4	2.8	27.80	10.07
4	27.9	30.2	2.3	29.05	7.92
5	26.4	31.8	5.4	29.10	18.56
6	31.8	31.5	0.3	31.65	0.95
7	39.4	29.1	10.3	34.25	30.07
8	28.6	29.2	0.6	28.90	2.08
9	28.0	26.2	1.8	27.10	6.64
10	31.2	35.2	4.0	33.20	12.05
11	37.6	31.8	5.8	34.70	16.71
12	26.9	29.0	2.1	27.95	7.51
13	30.7	28.0	2.7	29.35	9.20
14	31.9	26.8	5.1	29.35	17.38
15	28.9	36.2	7.3	32.55	22.43
16	27.8	31.4	3.6	29.60	12.16
				TOTAL	210.72

$$\overline{\%R} = \frac{210.72}{16} = 13.17$$

$$UCL = 3.267 \times 13.17 = 43.03$$

$$LCL = 0 \times 13.17 = 0$$

$D_3 = 0$ and $D_4 = 3.267$ when observations in each subgroup = 2

6.2.5.3 Construction of Coefficient of Variation Control Charts

- Calculate the arithmetic mean $\bar{x}$ for each sub-group of replicates.

- Calculate the standard deviation s for each sub-group of replicates using the formula

  $$s = \left(\frac{\sum (x-\bar{x})^2}{n-1} \right)^{0.5}.$$

- For each sub-group of replicates, calculate the coefficient of variation using the formula

  $$CV = \frac{s}{\bar{x}} (100)\%.$$

- Calculate the average coefficient of variation using the formula

  $$\overline{CV} = \frac{\sum_{j=1}^{N} CV_j}{N}$$

  when N = total number of sub-groups.

- Calculate the lower control limit using the formula

  $LCL = B_3 \overline{CV}$

  The value of B_3 is obtained from Appendix A-2.

- Calculate the upper control limit using the formula

  $UCL = B_4 \overline{CV}$

  The value of B_4 is obtained from Appendix A-2.

- Construct the Coefficient of Variation (CV) chart delineating the values of $\overline{CV}$, UCL, and LCL.

Figure 6-5 is an example utilizing the above procedure. The hypothetical data used and the necessary calculation are given in Table 6-5.

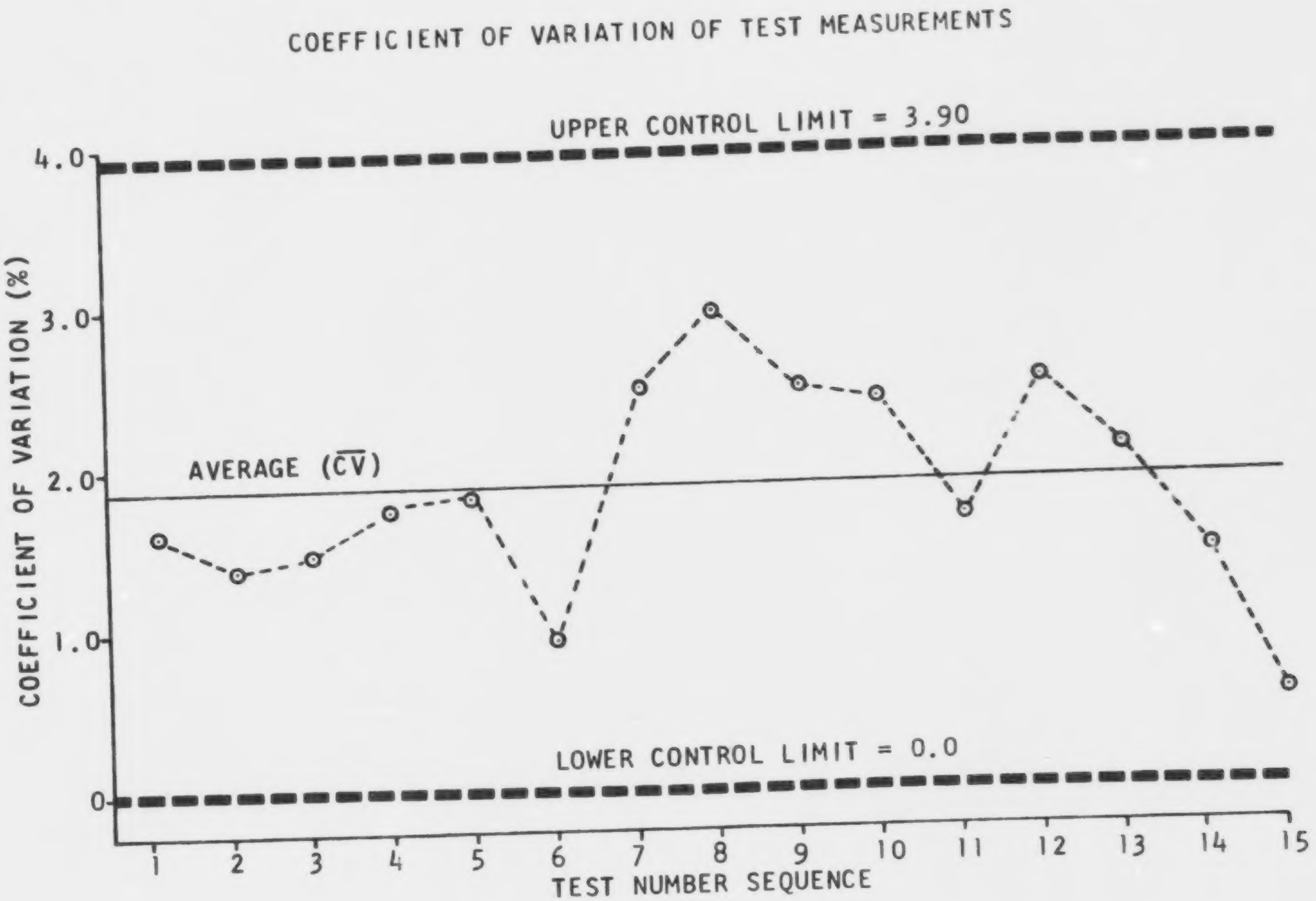


Figure 6-5. COEFFICIENT OF VARIATION CONTROL CHART

Table 6-5. TEST MEASUREMENTS - COEFFICIENT OF VARIATION CALCULATION

TEST NO.	x_1	x_2	x_3	x_4	x_5	$\overline{x}$	s	CV
1	.096	.094	.092	.093	.095	.0940	.0015	1.60
2	.189	.191	.187	.184	.185	.1875	.0026	1.39
3	.282	.279	.281	.276	.272	.2780	.0040	1.44
4	.378	.375	.369	.361	.370	.3706	.0065	1.75
5	.468	.456	.451	.446	.461	.4564	.0085	1.86
6	.556	.548	.541	.551	.553	.5498	.0057	1.04
7	.641	.631	.605	.613	.608	.6196	.0156	2.52
8	.720	.708	.670	.678	.687	.6926	.0208	3.00
9	.793	.745	.766	.755	.779	.7676	.0190	2.48
10	.856	.828	.841	.805	.816	.8292	.0201	2.42
11	.908	.880	.868	.893	.880	.8858	.0152	1.72
12	.922	.947	.934	.890	.900	.9186	.0235	2.56
13	.973	.952	.963	.933	.924	.9490	.0203	2.14
14	.988	.966	.951	.974	.981	.9720	.0143	1.47
15	.996	.981	.987	.992	.985	.9882	.0058	0.59
							TOTAL	27.98

$$\overline{CV} = \frac{27.98}{15} = 1.87$$

UCL = 2.089 x 1.87 = 3.90

LCL = 0 x 1.87 = 0

$B_3 = 0$ and $B_4 = 2.089$ when observations in each subgroup = 5

6.2.6 Accuracy Control Charts

Accuracy control charts are discussed in detail in Appendix H of Reference 6-1. There are occasions when variability in test results has been significantly affected by testing conditions difficult to control. For example, a sample may be selected and tested once a day in a situation where weather conditions significantly affect the test. Under such circumstances, a $\bar{x}$ chart does not give a true indication of lack of control, but only a lack of control of testing techniques, due to the confusing of effects in the variations of weather with any real variations in the quality of the test data. To overcome such difficulties the difference control chart has been devised (Reference 6-3). This technique requires the use of a standard unit or lot called the reference unit which is known to have an output controlled at the desired level. Such a unit or lot could be taken as part of the output that had been produced under controlled conditions, or it might have been made up as a result of artificial selection and 100 percent inspection. An application in mobile source emission testing would be the use of a correlation vehicle in comparing test measurements.

6.2.6.1 Construction of a Difference Control Chart

- Calculate the signed difference between the measurement from the current test unit (x_c), and the reference unit (x_r), i.e., $x_c - x_r$.
- Calculate the mean ($\bar{x}_{sd}$) and the standard deviation (s_{sd}) of the signed differences.
- The central line on the chart will be the mean of the signed differences.
- Calculate the upper and lower control limits for the chart using the formula

  $\bar{x}_{sd} \pm 3s_{sd}$ where $\bar{x}_{sd}$ = mean of signed differences
  s_{sd} = Std. deviation of signed differences

- Construct the Difference Control Chart delineating the central line, UCL, and LCL.
- Plot the signed differences ($x_c - x_r$) on the chart.

If points fall outside the above limits and assignable causes are found, the process is "out-of-control;" if no points fall outside the limits and there is no evidence of non-random variation within the limits, the process is said to be "under control with respect to its average," since variability in test results due to variations in testing conditions from day to day have been eliminated by taking differences.

Figure 6-6 is an example utilizing the above procedure in conjunction with the use of a correlation vehicle. Hypothetical data were used in the computations developed in Table 6-6.

6.3 STATISTICAL INFERENCE AND SOME APPLICATIONS OF ACCEPTANCE SAMPLING

This section discusses the meaning of statistical inference and how this concept can be used in developing an acceptance sampling procedure with respect to mobile source emission testing.

6.3.1 General Context

Statistical quality control is involved with quantitatively detecting and examining causes of variation in 1975 FTP testing and maintaining measurement quality at an optimum level. Control charts which were previously described are typically statistical techniques applied to a continual process (e.g., charting measurement data for equipment performance). However, what can be done to statistically analyze the properties of a group of data consisting of a finite number of measurements? Statistical inference and sampling theory can provide a solution to such a problem.

6.3.2 Definition of Statistical Inference

Statistical inference is a method which allows one to infer what is true about a population from the results of a sample drawn from it. This concept is very useful in that the quality of all elements within a group can be quantitatively determined without examining every element within the group. Acceptance sampling is an application of this method.

Why make use of statistical inference and sampling? Why not inspect 100 percent of all the components or data which constitutes a group? The answer, of course, is that it may be impractical (e.g., testing may be destructive) or too costly to inspect every element. Consequently, sampling can be a cost-saving statistical tool.

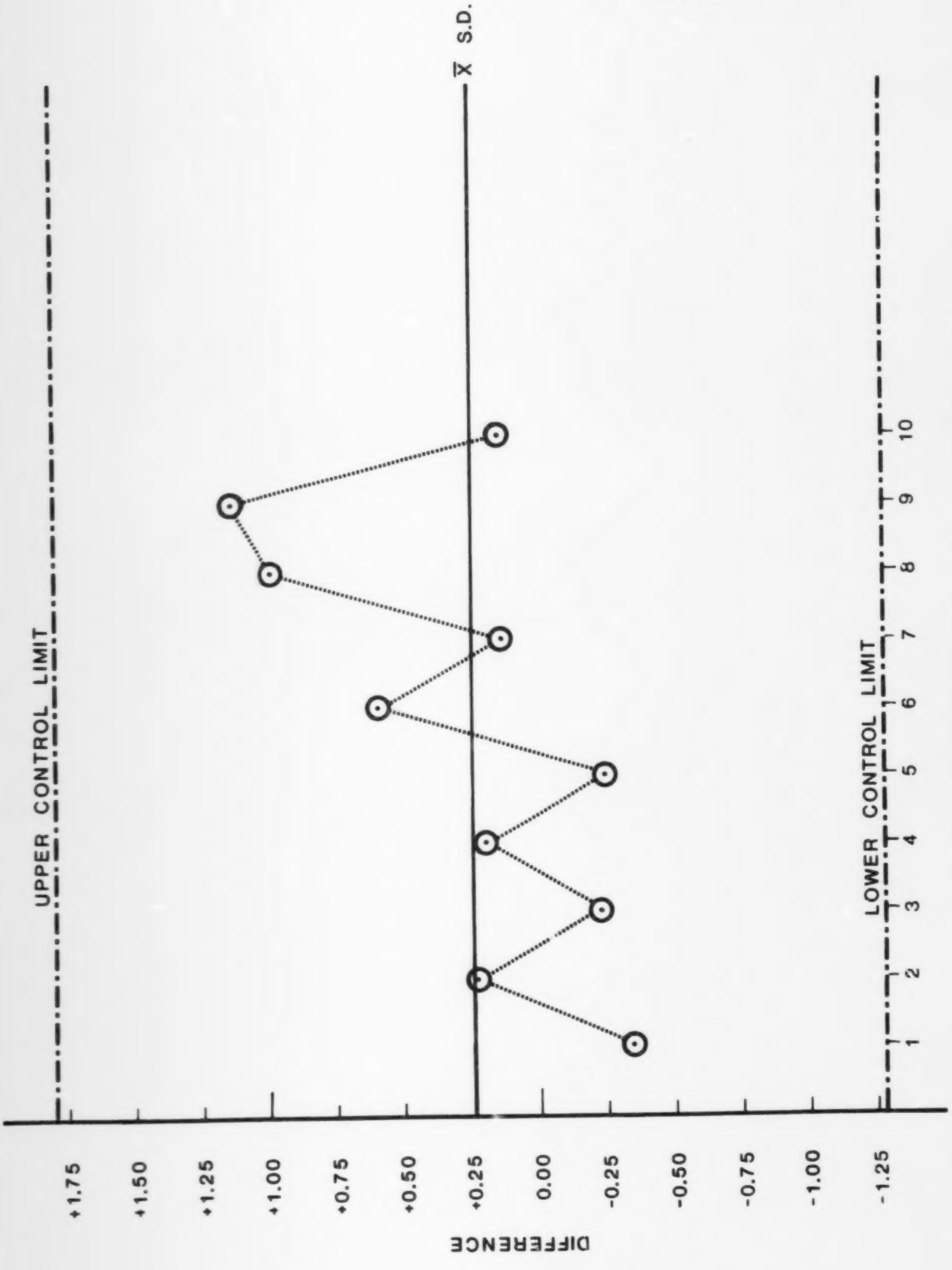


FIGURE 6-6. SIGNED DIFFERENCES CONTROL CHART

Table 6-6. HC CONCENTRATION MEASUREMENTS - CORRELATION VEHICLE VS CURRENT TEST VEHICLE

TEST NO.	HC MEASUREMENTS, G/M		SIGNED DIFFERENCE
	x_c	x_r	$(x_c - x_r)$
1	2.06	2.43	- 0.37
2	2.46	2.26	+ 0.20
3	2.21	2.46	- 0.25
4	2.37	2.20	+ 0.17
5	2.34	2.60	- 0.26
6	2.85	2.28	+ 0.57
7	2.91	2.79	+ 0.12
8	3.29	2.32	+ 0.97
9	3.36	2.24	+ 1.12
10	2.40	2.27	+ 0.13

$\bar{x}_{sd} = 0.24$

$s_{sd} = 0.51$

$$UCL = \bar{x}_{sd} + 3s_{sd} = 0.24 + 3(0.51) = 1.77$$

$$LCL = \bar{x}_{sd} - 3s_{sd} = 0.24 - 3(0.51) = - 1.29$$

6.3.3 Application of Sampling Theory in Mobile Source Emission Testing

Sampling theory can be used with respect to many aspects of 1975 FTP testing. Some of these applications are as follows:

- Inspection of incoming lots of procured materials (e.g., gas bottles)
- Determining frequency of checks in evaluating 1975 FTP measurement systems performance and 1975 FTP test results, sampling from past six month's data
- Determining frequency of zero/span checks in evaluating HC, CO, CO_2, and NO_x gas analyzer performance, sampling from past six month's data.
- Determining frequency of multi-point calibration, sampling from past six month's data
- Determining frequency of checks in validating data (e.g., recorded gas analyzer strip charts), sampling from past six month's data.

There is a detailed discussion of statistical sampling in Appendix I of Reference 6-1.

6.4 ANALYSIS OF VARIANCE

This technique provides an objective method of dealing with the total variation within a test. By breaking down this variation into the contributions of main effects, interaction and residual effects, valid conclusions can be made regarding the test data through the use of statistical methods. The test must be designed to allow extraneous influences to operate in a truly random manner. To obtain valid conclusions from the test it is necessary to maintain proper control of other variables in addition to those being investigated. Uncontrollable or unknown conditions occur in most tests. Conditions such as temperature variation, operator efficiency, equipment repeatability, and variation among related items included in the test but not under control are only a few of the possibilities to be considered.

6.4.1 Basic Theory

The analysis of variance provides an indication as to whether or not the observed differences among the means of the samples are significant, that is, greater than those variations which can be attributed solely to sampling fluctuation. To do this, the variance is computed using two methods. The F test is then used to quantitatively determine the significance between the values obtained using each method. A more detailed description of analysis of variance theory and its applications can be found in References 6-4 and 6-5.

6.4.2 Analysis of Variance Implementation in Mobile Source Emission Testing

The analysis of variance objectively determines if significant differences exist between groups of sampled data. Such a technique is useful in quantitatively examining the repeatability of a given measurement system. Accuracy of measurement systems can also be evaluated using the analysis of variance. In the measurement of exhaust emissions from a given vehicle there are three levels of variability, i.e., variabilities associated with a given test cell, cell-to-cell variability within a given laboratory site, and laboratory-to-laboratory variability. Factors affecting variability include the vehicle, ambient condition, dynamometer, CVS, analyzer, calibration gas, operator and the computer. The statistical significance of any of these factors on the test results can be evaluated by using the analysis of variance technique. This technique can be used to evaluate the differences in performance of various CVS systems, catalytic converters, etc., and to determine the significance of reduction in exhaust emissions as the result of scheduled maintenance procedures.

The following is an example comparing gas emissions from three cars tested five different. An analysis of variance test (Table 6-7) is computed to determine if there are any significant differences between cars. The area of interest will be the effect of one factor only on the gas emission measurements, in order to demonstrate the computational set-up for a one-factor analysis of variance. The factor, car type, is said to be in three categories as there are three cars, and it is assumed that these are the only cars to be concerned with. It is not desired to generalize the results to other car types of which the three might be a random sample. This is an important point. As only these three car types are being considered, the factor is in a fixed category. If the engineer is interested in these three car types as a random sample of a whole population of car types, car types would be a random effect. In a one way classification (one factor) like this one, the analysis used to obtain the results would be the same for either a random or fixed effect, but the significance tests performed would be interpreted differently. This discussion will be confined to designs with fixed factors only.

Now, some engineer notes that five different sample gases were used in these tests and realizes that further data analysis would determine if there were possible differences due to the different gas samples. The problem now becomes an analysis of variance (Table 6-8) with a two-way classification of the data, i.e., two factors: car type and gas sample, one in three categories (three car types) and the other in five categories (5 gas samples). Again it is assumed that the five gas samples are the

Table 6-7. ANALYSIS OF VARIANCE - ONE-WAY CLASSIFICATION
GAS CONCENTRATION MEASUREMENTS FROM THREE CARS

TEST NUMBER	EMISSION MEASUREMENTS		
	CAR TYPE 1	CAR TYPE 2	CAR TYPE 3
1	6.6	6.6	7.0
2	7.2	6.4	6.0
3	6.4	7.0	5.0
4	7.4	6.2	5.8
5	7.8	6.8	7.0
SUMS	35.4	33.0	30.8
SUMS OF SQUARES	251.95	218.20	192.64

$$\text{TOTAL S.S.} = 662.79 - \frac{(99.2)^2}{15} = 6.75$$

$$\text{CAR S.S.} = \frac{(35.4)^2 + (33.0)^2 + (30.8)^2}{5} - \frac{(99.2)^2}{15}$$

$$= 658.16 - 656.04 = 2.12$$

A.O.V. SUMMARY					
SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	$F_{.05}$
TOTAL	6.75	14			
AMONG CARS	2.12	2	1.06	2.74*	3.89
ERROR	4.63	12	.386		

*Not significant at 5 percent level of significance.

Table 6-8. ANALYSIS OF VARIANCE - TWO-WAY CLASSIFICATION
GAS CONCENTRATION MEASUREMENTS FROM THREE CARS
USING FIVE DIFFERENT GAS SAMPLES

GAS SAMPLE	EMISSION MEASUREMENTS			SUMS
	CAR TYPE 1	CAR TYPE 2	CAR TYPE 3	
1	6.6	6.6	7.0	20.2
2	7.2	6.4	6.0	19.6
3	6.4	7.0	5.0	18.4
4	7.4	6.2	5.8	19.4
5	7.8	6.8	7.0	21.6
SUMS	35.4	33.0	30.8	99.2
SUMS OF SQUARES	251.95	218.20	192.64	662.79

TOTAL S.S. = 6.75 (from Table 6-7)

CAR S.S. = 2.12 (from Table 6-7)

$$\text{GAS SAMPLE S.S.} = \frac{(20.2)^2 + (19.6)^2 + (18.4)^2 + (19.4)^2 + (21.6)^2}{3}$$

$$- \frac{(99.2)^2}{15} = 657.89 - 656.04 = 1.85$$

A.O.V. SUMMARY					
SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	$F_{.05}$
TOTAL	6.75	14			
AMONG CARS	2.12	2	1.06	3.03*	4.46
AMONG GAS SAMPLES	1.85	4	0.46	1.31*	3.84
ERROR	2.78	8	0.35		

*Not significant at 5 percent level of significance.

only gases of interest, i.e., gas samples are a fixed factor. As each gas has been used with each car type, the data can be analyzed for differences in gas emissions among gas samples as well as among car types. The results show that neither the car types or the gas sample types produce a significant difference in the gas emission measurements even though the error term has been reduced by accounting for another possible source of variation. In the first example (one-way classification) the gas sample effects were included in (i.e., "confounded") with the error term. In actual practice, this other source of variation should have been foreseen in the original design and set up as a two-way classification model. Reference 6-4 contains applications involving random effects.

6.5 DATA VALIDATION

Documentation of measured emissions should precisely and accurately indicate the concentration of the exhaust gases being sampled. Accuracy in recording data, however, depends on the recording techniques implemented. Methods that have been extensively researched, evaluated, and controlled should have minimal error.

Error due to human factors is one source of inaccuracy in measurement reporting. Human errors include (1) incorrect reading of instrumentation, (2) mistakes in computing results, and (3) mistakes in transposing data from one form to another such as keypunching errors when computers are used. Human error cannot be totally eliminated; however, it can be considerably reduced.

Instrumentation is another source of error in documenting measurements, and cannot be totally eliminated as there continually exists a random inaccuracy for any measurement system, which cannot be completely removed, as was discussed earlier in this section.

Data validation involves the processing of raw measurement data generated from emission measurement systems. This processing includes a critical review of data in order to locate spurious, documented values. It may consist of cursory scans to identify any extreme values, or extensive examinations requiring sophisticated data processing techniques. In either case, when a spurious value is identified, it is not immediately rejected. Rather each questionable value must be checked for validity.

Data validation can occur at different steps within the total measurement process. Additionally, there exist numerous data validation techniques. Among the most commonly used are:

- Impossible value sorting (i.e., identify and eliminate data with impossible values)

- Improbable value sorting (i.e., identify and eliminate data with improbable values)

- Identification of abrupt shifts in data levels
- Identification of stuck values
- Analysis of calibration data acceptability
- Use of computer data checks

6.5.1 Data Validation For Manual Techniques

Specified, experienced laboratory personnel should inspect testing data. At regular intervals, daily or weekly, results should be scanned for questionable values. This type of validation is most sensitive to extreme values, i.e., either unusually high or low readings.

The criteria for determining an extreme value are derived from required, specified values expected, and from prior data. The data used to determine extremes may be the minimum and maximum concentrations from prior data or may be derived from control chart limits established in accordance with the techniques outlined earlier in this section.

The time spent checking data that has been manually reduced by technicians depends on the time available and on the demonstrated abilities of the technicians to follow the detailed computation procedures. At this time no agencies appear to be using a specific formula for determining how much data should be checked for validity in a manual data reduction system. One air pollution control agency approached the problem in the following manner: (1) a senior technician or supervisor was assigned to check approximately 10 percent of the data interpreted by each of four or five technicians. The 10 percent figure was arbitrary based on time availability and experience in finding errors. (2) Data was checked for obvious trends or unusual values indicating possible reader bias. (3) No statistical formula was applied to determine the significance of differences between readings interpreted by the technician and readings interpreted by the senior technician or supervisor. If the two values differed by more than two digits in the last significant figure, the data was judged unacceptable. (4) Each analyst's technique of data interpretation was checked against written procedures describing the use of graphic aids to determine if those graphic aids had been properly used. The most significant errors originated from the technician deviating from the written procedures - not from random error (Reference 6-10).

6.5.2 Data Validation For Computerized Techniques

Computers are used not only to store and retrieve data but also to validate data. Data validation requires the development of a specialized computer program. The techniques for identifying and sorting extreme values in manual techniques also apply here.

The extent of the decision elements to be used in data validation cannot be defined for the general case. Rather, the validation criteria should be tailored such that they coincide with time, man-power required, accuracy, and cost constraints.

6.5.3 Statistical Validation in Maintaining Data Quality

A statistical analysis of historical data can be used as a diagnostic tool in data validation. For example, the total data history of homogenous groups can be compared for relationships in spatial patterns of results.

The output from the emission analyzer device is often an analog trace on a strip chart. Reading strip charts is a tedious job subject to varying degrees of error. A procedure for maintaining a desirable quality for data manually reduced from strip charts is important. One procedure for checking the validity of the data reduced by a technician is to have another technician or the supervisor check the data. Because the values have been taken from the strip chart by visual inspection, some difference in the values derived by two individuals can be expected. When the difference exceeds a specified amount and the initial reading has been determined to be incorrect, an error should be noted. If the number of errors exceeds a predetermined number, all data for the strip chart are rejected and the charts are read again by a technician other than the one who initially read the chart. Acceptance sampling techniques are appropriate for use in such situations. These techniques and the theory of statistical sampling are discussed in Appendix I of Reference 6-1, and Part III of Reference 6-2.

6.5.3.1 Outlier Analysis

The treatment of outliers has had to be considered by every data analyst who at some time or another has obtained a set of observations, supposedly taken under the same conditions, in which one observation was widely different from the rest. The problem is whether the suspect observation should be kept in the computation or whether it should be discarded as being a faulty measurement. During mobile source emission testing, frequently one value within a data set may appear to be considerably different from the other values.

Many criteria have been proposed as guidelines in the rejection of observations. An excellent summary and critical review of the classical rejection procedures and some of the more modern ones is provided in Reference 6-6. A famous classical rejection rule is "Chauvenet's criterion," which is based on the normal distribution and advises rejection of an extreme observation if the probability of occurrence of such a deviation from the mean of the n measurements is less than 1/2n. For a small n, such a criterion rejects too easily, and a more appropriate test in such circumstances would be the Dixon Ratio Test (Reference 6-7). This test makes use of only the data in hand, and implements the statistics:

	If X_1 is suspect		If X_n is suspect	Most sensitive criterion when
$r_{10} =$	$\frac{X_2 - X_1}{X_n - X_1}$	or	$\frac{X_n - X_{n-1}}{X_n - X_1}$	$3 \le n \le 7$
$r_{11} =$	$\frac{X_2 - X_1}{X_{n-1} - X_1}$	or	$\frac{X_n - X_{n-1}}{X_n - X_2}$	$8 \le n \le 10$
$r_{21} =$	$\frac{X_3 - X_1}{X_{n-1} - X_1}$	or	$\frac{X_n - X_{n-2}}{X_n - X_2}$	$11 \le n \le 13$
$r_{22} =$	$\frac{X_3 - X_1}{X_{n-2} - X_1}$	or	$\frac{X_n - X_{n-2}}{X_n - X_3}$	$14 \le n \le 25$

X_i denotes either individual values or means of data sets arranged in order of magnitudes from X_1 to X_n. It is assumed that the distribution of X or $\bar{X}$ is normal. In using this method, the samples from which the means are computed should all have the same size. The critical values for r_{10}, r_{11}, r_{21}, and r_{22} can be found in Table W of Reference 6-4.

An example using this technique would be to suppose that six vehicles of the same type were tested for CO exhaust emissions. The CO emissions in parts per million were as follows:

Vehicle	CO Emissions in Parts Per Million
A	510
B	521
C	523
D	501
E	493
F	605

The problem is to test whether vehicle F belongs with others of the group. To perform the test r_{10} is computed where

$$r_{10} = \frac{X_6 - X_5}{X_6 - X_1} = \frac{605 - 523}{605 - 493} = \frac{82}{112} = 0.732$$

The critical value is 0.56 for $\alpha = .05$ per the referenced tables. Therefore, since the computed valued of r_{10} (0.732) is greater than 0.56, it can be concluded that F should be judged different from the others. Note that this technique bases its conclusion solely upon the six values and not on an outside measure of error.

6.6 METHODS OF CALIBRATION CURVE CONSTRUCTION

Least squares, and Curveall (modified least squares) are numerical analysis techniques which can be used to construct calibration curves. Although other curve fitting techniques exist, the above are among the most commonly used. This section describes general considerations in constructing calibration curves, the theory behind each of the above techniques, and how each can be implemented. Additionally, the pros and cons of each method are discussed.

6.6.1 General Context of Calibration Curve Construction

Instrumentation provides a means for describing the contents of a sample in terms of specific, quantifiable measurement data. By translating the sample contents into meaningful data a functional relationship is constructed; in the case of calibrating gas analyzers, meter deflection or digital display is expressed as a function of sample content. Construction of calibration curves is the process of attempting to mathematically duplicate the aforementioned functional relationship using numerical analysis techniques. Several of these techniques, including least squares, are discussed in Appendix J of Reference 6-1.

Consideration should be given to the following when constructing calibration curves. Usually regardless of the technique, the error between some or all of the data points and the corresponding estimated dependent variable value should be computed. Such a practice provides an indication of the generated curve's accuracy.

In general, it is recommended that the most accurately representative curve fitting technique (i.e., in terms of realistic system response and standard's accuracy) for a given procedure be determined through experience. For example, experience dictates that the response of a CO analyzer is not expected to be represented by a sixth order polynomial. This technique should then continue to be used for that procedure providing that the hardware or procedure remain unchanged. It is recommended that the curve fitting technique not be continually changed so that the generated curve best fits a particular set of data for a given procedure. In other words, the procedure and hardware dictate the type of technique to use and not the data set generated each time an item is calibrated.

6.6.2 Curveall

The Curveall curve fitting technique is a modified version of the least squares technique discussed previously. Using Curveall, a polynomial of the following form is assumed

$$d = \frac{c}{A_0 + A_1c + A_2c^2 + A_3c^3}$$

where c is the independent variable, d is the dependent variable, and A_i are the coefficients that will be estimated using the least squares technique. The A_i coefficients are determined by minimizing the sum of the squares of the errors. A detailed discussion of the Curveall techniques is contained in Reference 6-8.

6.6.3 Summary of Curve Fitting Techniques

The aforementioned curve fitting techniques each have distinct advantages and disadvantages. Table 6-9 is a summary of the techniques in this regard.

6.6.4 General Considerations

The number of data points which must be obtained to derive 1975 FTP calibration curves is specified in the Federal Register. The number of data points is roughly dependent on the order of the polynomial which realistically represents the system response being plotted. However, it should be noted that specific curve fitting techniques are better to use in particular situations. For example, in the case where the system response is not linear, the Curveall or other non-linear methods would generate a more accurate and realistic curve.

Table 6-9. MERITS AND DISADVANTAGES OF TWO CURVE FITTING TECHNIQUES

	LEAST SQUARES	CURVEALL (MODIFIED LEAST SQUARES)
MERITS	Smooths data into a continuous functional response Computer processing time is relatively short compared to other techniques	Smooths data into a continuous functional response Forces curve through the origin Third order fit determined to be an appropriate response
DISADVANTAGES	Care must be taken to determine which order polynomial is most appropriate; e.g., second order may not represent true instrumentation response	Curve may fit data too closely; inflection points introduced which may not reflect true instrumentation responses* Computer processing time relatively large

*This situation occurs when standard gases have significant inaccuracies. Hence, the curve incorporates these inaccuracies since polynomials closely fit data points.

6.7 THE USE OF PROBABILITY PAPER

In the previous sections covering control charts and analysis of variance, it was often assumed that the compiled data formed a normal distribution. Through the use of probability paper, one can determine what the form of the distribution actually is, whether it be normal, Poisson, etc. In addition probability paper graphically illustrates the cumulative distributions as they relate to compiled data.

Probability paper is ruled so that the plot of some particular distribution function will appear as a straight line. Normal probability paper (commonly called "probability paper") will straighten out the normal distribution as shown in Figure 6-7. This paper can usually be obtained in various forms from any good source of drafting supplies.

As an example of the use of this paper, the values of the data versus the cumulative percent frequency (Table 6-10) are plotted in Figure 6-8. In this particular example, the variability of CO emission levels from a fleet of catalytic converter vehicles during a cold stabilized portion of the Federal driving cycle is being examined.

The following are the steps taken to plot data on probability paper:

1. Arrange the observations in ascending values. The smallest value is given a rank of 1 and the largest value a rank of n.

2. For each value, calculate the cumulative frequency.

3. For each value, calculate $\frac{\text{cumulative frequency}}{n + 1} \times 100$.

   This provides the mean rank probability estimate, in percent, for plotting the data.

4. Plot the observed values against their mean rank probability estimate.

When the observations are in a frequency distribution form, the procedure is the same except that instead of using the observed values, the probability estimates are plotted against the cell boundaries, as illustrated in Table 6-10. The plot is shown in Figure 6-8. Lower cell boundaries are plotted against the last column of Table 6-10. A straight line is drawn in by eye and the fit appears to be reasonable. If the sample is supposedly representative of a universe, then that line characterizes the distribution describing that universe. From it, one can obtain the probability corresponding to any of the values included in the population.

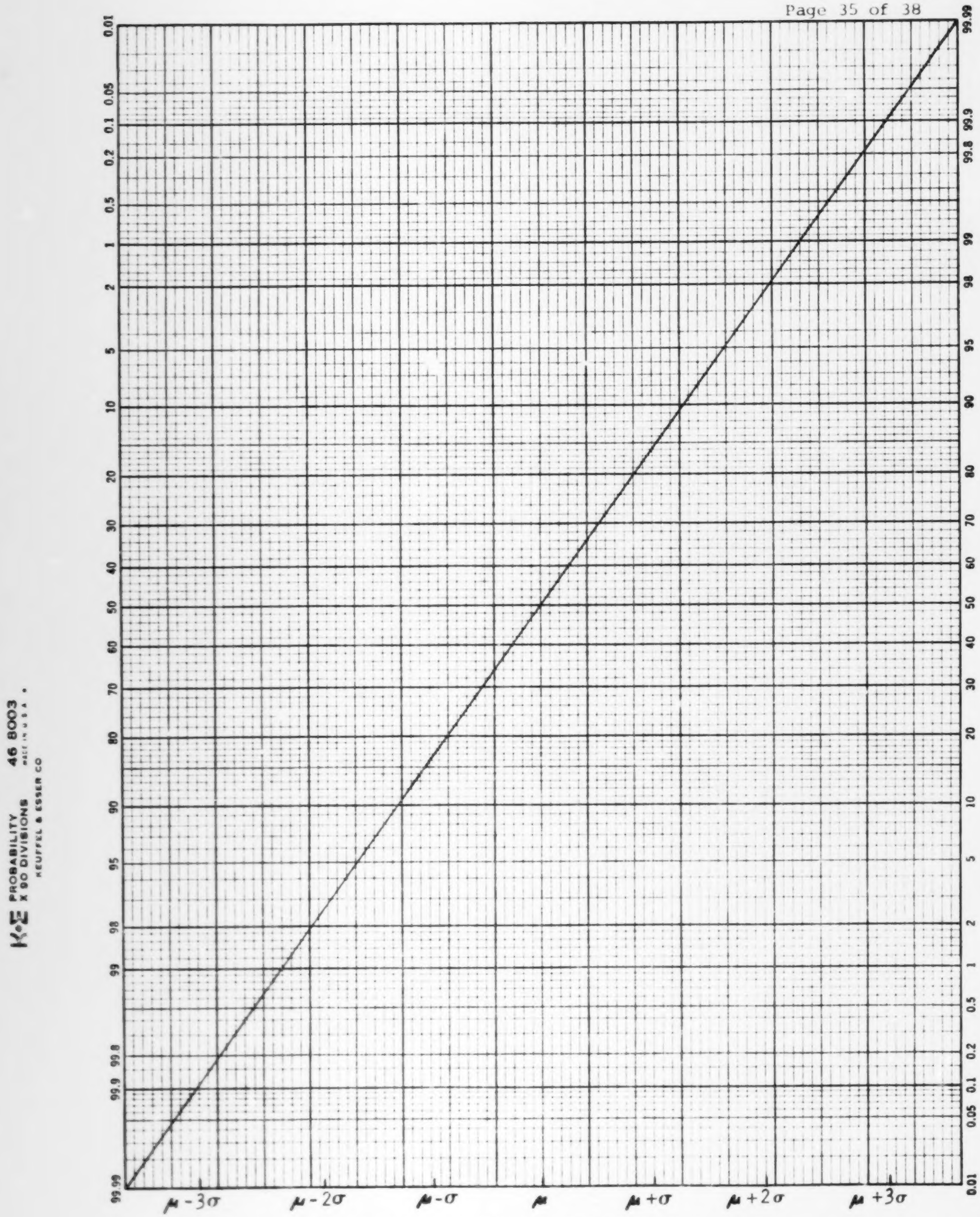


Figure 6-7. NORMAL PROBABILITY PAPER

Additionally, in Figure 6-8, an ordinate at 12 ppm has been erected to show that this technique predicts that 9 percent of future tests will result in CO emission levels less than 12 ppm. The standard deviation can be estimated by the perpendicular distance between the intersections of the 50 percent and 84 percent abscissas with the graph line.

Since the data in this case tends to form a straight rather than a curved line on the probability paper, one could conclude that the sample did form a normal distribution. If the data tends to form a curved line, other types of probability paper could be used to determine the type of distribution the data actually form.

Probability graph paper is available for the normal, log-normal, experimental, Weibull and other probability distributions. It can be used to detect outliers, to derive control charts limits and there are many other applications which are adequately discussed in Reference 6-9.

Table 6-10. TABULAR DESCRIPTION OF CO EMISSION LEVELS IN PPM

EMISSION LEVEL	FREQUENCY	CUMULATIVE FREQUENCY	CUM. % $\left(\frac{\text{CUM FREQ}}{n+1}\right) \times 100$
9.5-10.4	2	2	99
10.5-11.4	2	4	1.98
11.5-12.4	6	10	4.95
12.5-13.4	18	28	13.86
13.5-14.4	26	54	26.73
14.5-15.4	32	86	42.57
15.5-16.4	42	128	63.37
16.5-17.4	30	158	78.22
17.5-18.4	24	182	90.10
18.5-19.4	12	194	96.04
19.5-20.4	4	198	98.02
20.5-21.4	2	200	99.00

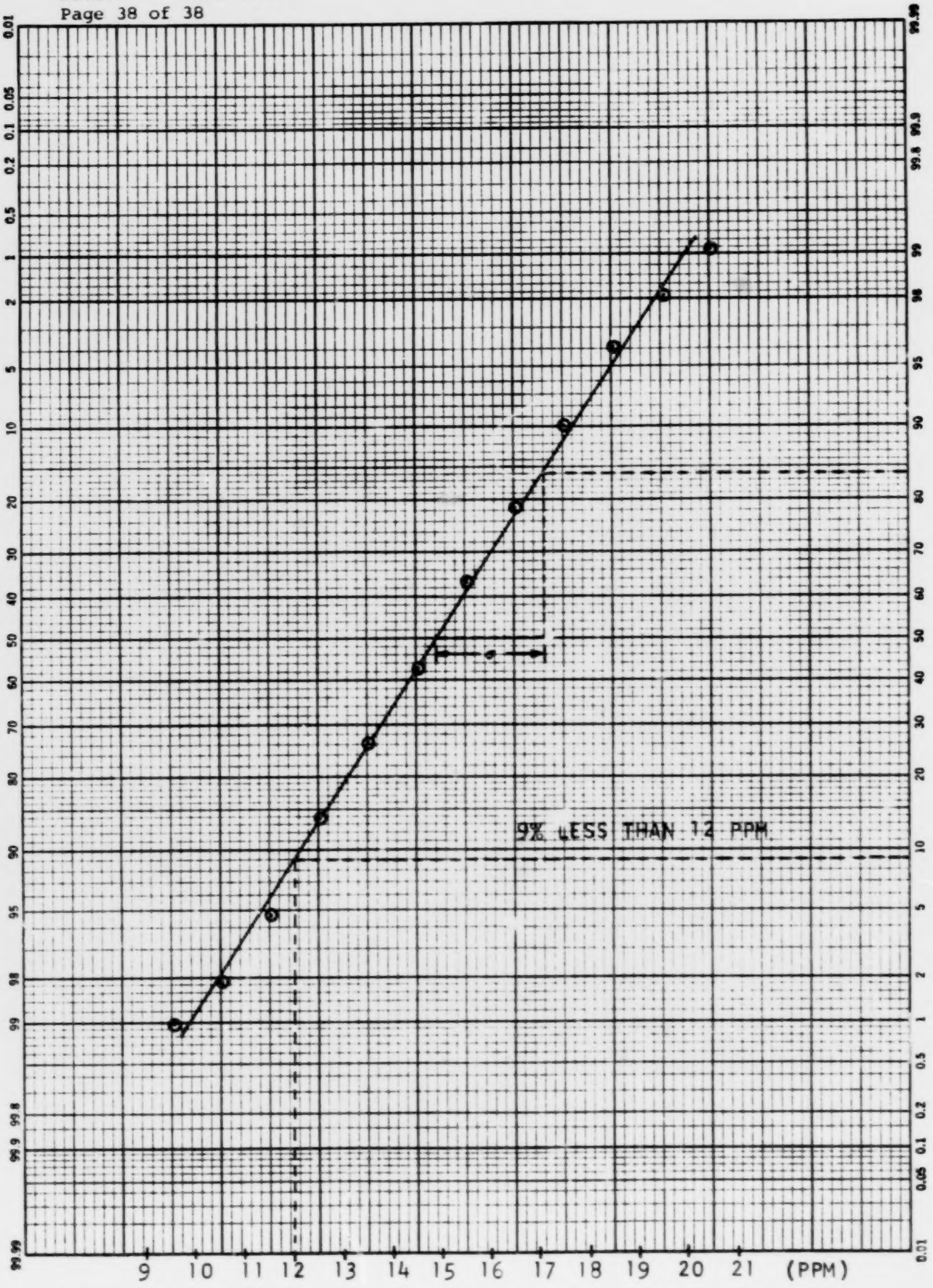


Figure 6-8. NORMAL PROBABILITY PAPER (CO EMISSION LEVEL)

Section 7

ANALYSIS OF VARIABILITY IN THE MEASUREMENT OF EMISSIONS FROM HEAVY DUTY DIESEL ENGINES

Identification, control and quantification of variables is a required objective in a program to assess the reliability of a measurement system. The precision and accuracy of mobile source emission measurements are dependent on the variability existing in the engine operation and the measurement system. Although these guidelines reflect the current state-of-the-art, EPA is conducting extensive studies to specifically quantify the major contributions to heavy duty emissions test variability.

Test procedures and equipment specifications will be made more definitive and quality provisions (acceptability criteria) will be added to improve the accuracy and precision of the total measurement system.

Interlaboratory variability by engine manufacturer had been studied through an analysis of data obtained by the EPA from the engine certification tests. Although the total measurement system variability is of prime importance, it is essentially a composite of all variables and will only be useful for predicting overall test variation between the laboratories or test cells involved in the program. If bias should exist in one or both systems being compared e.g., the use of a gas deviating from the acceptable standard, the cause of the variation between systems will not be identified.

A knowledge of specific variables significantly affecting the data is a prerequisite for achieving a predetermined goal, improving data reliability and detecting bias factors in the system. These variables are either determinate or indeterminate. Determinate variables may be objectively studied, but the nature of indeterminate variables require subjective evaluation. Indeterminate variables are usually estimated through experience with the measurement system, engineering evaluation of the test procedure and statistical analyses of the data.

The measurement system for heavy duty diesel engines involves the measurement of smoke and gaseous emissions. In addition to engine inconsistencies certain measurement system variables have been established as prime sources of error. Efforts to reduce these variables include the use of instruments and calibration standards having improved precision and accuracy, and improvement in methods of sampling gaseous emissions.

The purpose of this section of the guideline is to discuss the methods used to identify these major sources of variation, to quantify the effect of the determinate variables and the involvement of Quality Assurance in the effort to reduce test variables.

7.1 VARIABLES ASSOCIATED WITH THE MEASUREMENT OF SMOKE EMISSIONS

The Federal smoke emission test is designed to determine the opacity of smoke in exhaust emissions using a continuous recording, full flow light obscuration (opacity) meter. The engine dynamometer cycle utilizes engine operating conditions which tend to promote smoke from diesel engines. The smoke emitted during acceleration and lugging modes is monitored continuously and opacity values are averaged for each half second interval. Three identical cycles are run following a 10 minute preconditioning mode.

The primary sources of variability in this procedure are generally considered to be the

- Dynamometer Operation
- Diesel Engine Operation
- Smokemeter
- Recorder
- Ambient Conditions
- Chart Reading
- Computer

The contributions to total test variability from each of these sources will vary from one laboratory to another and even from cell-to-cell within a test facility because of the wide variations permitted in the design of the measurement system.

Methods for controlling these variables include:

- Application of computer automation techniques
- Frequent maintenance and calibration of the smokemeter and recorder
- Application of statistical quality control techniques as an "early warning" system to detect impending problems.

7.1.1 Dynamometer Operations

The dynamometer speed and torque meters are calibrated at monthly intervals. The associated recorders are checked and aligned with the meters prior to each test. The RPM output is checked with a primary standard such as a strobotac with a standard accuracy of ±1 percent. The torque meter is usually calibrated using weights placed on the torque beam. The weights should be traceable to the NBS and should have an accuracy of ±0.1 percent. The test variability associated with the operation of the dynamometer would be difficult to assess without an extensive program involving several operations, dynamometers and engines.

Computer controlled dynamometers have become quite popular; however, these systems require manual intervention, with its associated inherent variability to program the computer each time an engine is installed in the test cell.

The test cycle is operated according to engine RPM within the specified tolerance for a particular mode. Speed-torque traces are made for each test and those not meeting the RPM tolerance are voided and the test is rerun.

An assessment of this dynamometer variable could be achieved by performing 10 consecutive tests (cycles) on a well preconditioned engine using the same computer program or operator alternated with 10 consecutive tests during which the RPM is varied within the specified limits during the cycle, using different operators if possible. Comparison of the variability (S^2) of the two sets of "a", "b" and "c" factors (F.R. Ref. 85.874-18, para. (a)(b) and (c)) would give an objective assessment of the variability due to dynamometer operation. Naturally this would only be valid for that particular engine-dyno combination. The test would be repeated with different engine-dyno combinations each time a new engine is installed. A Coefficient of Variation control chart as described in Section 6.2.5.3 could be established using the collected data. The analysis of variance techniques also referred to in Section 6 could be applied to determine significant differences between the various combinations.

7.1.2 Diesel Engine Operation

The preconditioning of the engine and its operation during the test cycle may be two of the greatest contributors to test variability. They have not received the detailed attention associated with the preconditioning and testing of light duty vehicles (Ref. Phase I Report). The prescribed test requires a ten minute preconditioning of a "warm" engine at maximum rated horsepower. The monitoring of engine operating parameters such as fuel and air flow, engine and exhaust temperatures, fuel temperature and pressure, and inlet/exhaust pressures as is done in the gaseous test provides valuable information for the detection of engine malfunction or change in operating characteristics. Engine variability is associated with determination of gaseous and smoke emissions and is discussed further in Section 7.3.

7.1.3 Smokemeter and Recorder

The smokemeter type and specifications are defined by the Federal Register in paragraph 85.874-13 and in test procedure TP-751 in Volume II. Smokemeters meeting these specifications are available from several instrument manufacturers. They are usually supplied with a primary set of neutral density filters having calibration traceable to NBS. The primary set of filters are sent to the EPA, Ann Arbor Facility annually for calibration and verification. These filters have a calibrated accuracy of ±1 percent, traceable to EPA or NBS. It is important to handle and clean filters carefully since any contamination on a filter may change its opacity value.

Filters having a nominal opacity of 10, 20 and 40 percent are used to verify the linearity of the smokemeter output prior to each test. Zero and 100 percent points are checked before and after the test. Changes in instrument calibration in excess of ±2 percent during the test require a readjustment, re-calibration and repetition of the test.

The following table summarizes instrument characteristics that are major sources of error in smoke measurement.

Table 7-1. MAJOR SOURCES OF ERROR IN SMOKE MEASUREMENT

CHARACTERISTIC	TOLERANCE	ESTIMATED COEFFICIENTS OF VARIANCE
Drift	±2 percent	0.5 percent
Noise	±1 percent	0.25 percent
Linearity	±2 percent	0.5 percent
Calibration Filter	±1 percent	0.25 percent
Recorder Response	0.5 Sec full scale	0.5 percent
Maintenance	Indeterminate	1.0 percent
	Total Variance =	1.37 percent

The acceptable tolerances shown in the table are from the Federal Register. Estimated coefficients of variance are listed as examples of what might be typically expected if these characteristics were determined experimentally in the laboratory. The total variability is estimated from the square root of the sum of the squares of the individual coefficients of variance.

7.1.4 Ambient Conditions

The humidity barometric pressure air circulation and temperature in the test cell can affect the operation of the instruments as well as the engine.

Relative humidity is almost universally determined in the emission laboratory using the wet bulb-dry bulb hygrometer. Other methods of determining humidity are available but attempts to correlate the various methods have usually met with some unsolved discongruity. Therefore, it is mandatory that the equipment used for humidity determination should be specified. Two basic types are presently used: the fan-type hygrometer with either thermocouples or thermometers and electronic or visual read out. The other is the sling-type psychrometer. These two types are known to give equal readings.

A comparison of readings, on an audit basis, of these two types could be used as a check. The sling psychrometer is the preferred audit tool because of its portability.

Other recommended methods for reducing variability include a controlled test lab environment, and continuous recording of humidity during a test. Wicks and water supply should be inspected frequently for contamination. Thermocouples and thermometers should have a calibrated accuracy of ±0.5°F or better.

The temperature compensated aneroid barometers, calibrated against a standard laboratory mercury barometer are frequently used in the measurement system. In laboratories with only a single test cell a mercury barometer is often used. The two primary sources of error for barometer readings are in calibrating the aneroid barometer and errors in the reading of a mercury barometer. Calibration errors are generally controlled through independent checks. Errors in reading the barometer can be reduced by recording the pressure before and after the test. Comparison of the range of the two readings could be done by data validation or a computer, utilizing one of the control chart techniques described in Section 6. Comparison to the reading of the previous test on the same day would provide an additional check.

The air circulation and venting system should be controlled so that the smoke plume and engine temperatures are not affected, and to prevent "hot" spots or sudden changes in temperatures in the area where the instrumentation is located.

The temperature of the cell is specified to be between 68° and 86°F (20-30°C). If tests are consistently run at one extreme the test results will generally differ from those run at the other and of the 18 degree range. Ideally, temperatures should be controlled to within ±3°F of the mid point of this temperature range.

7.1.5 Chart Reading

Data calculations for smoke opacity are performed in the following manner:

(a) Locate the acceleration modes and the lugging mode on the chart. Divide each mode into one-half second intervals beginning at the start of each mode. Determine the average reading during each one-half second interval except those recorded during the transitional portions of the cycle.

(b) Locate and record the fifteen highest one-half second readings during the acceleration mode of each cycle.

(c) Locate and record the five highest one-half second readings during the lugging mode of each cycle.

(d) Record the three highest values of the above 20 readings.

(e) Repeat the recordings required in steps (a), (b) and (c) for a total of three cycles required by the test procedure.

(f) Average the 45 readings by the acceleration mode and designate the value as "a".

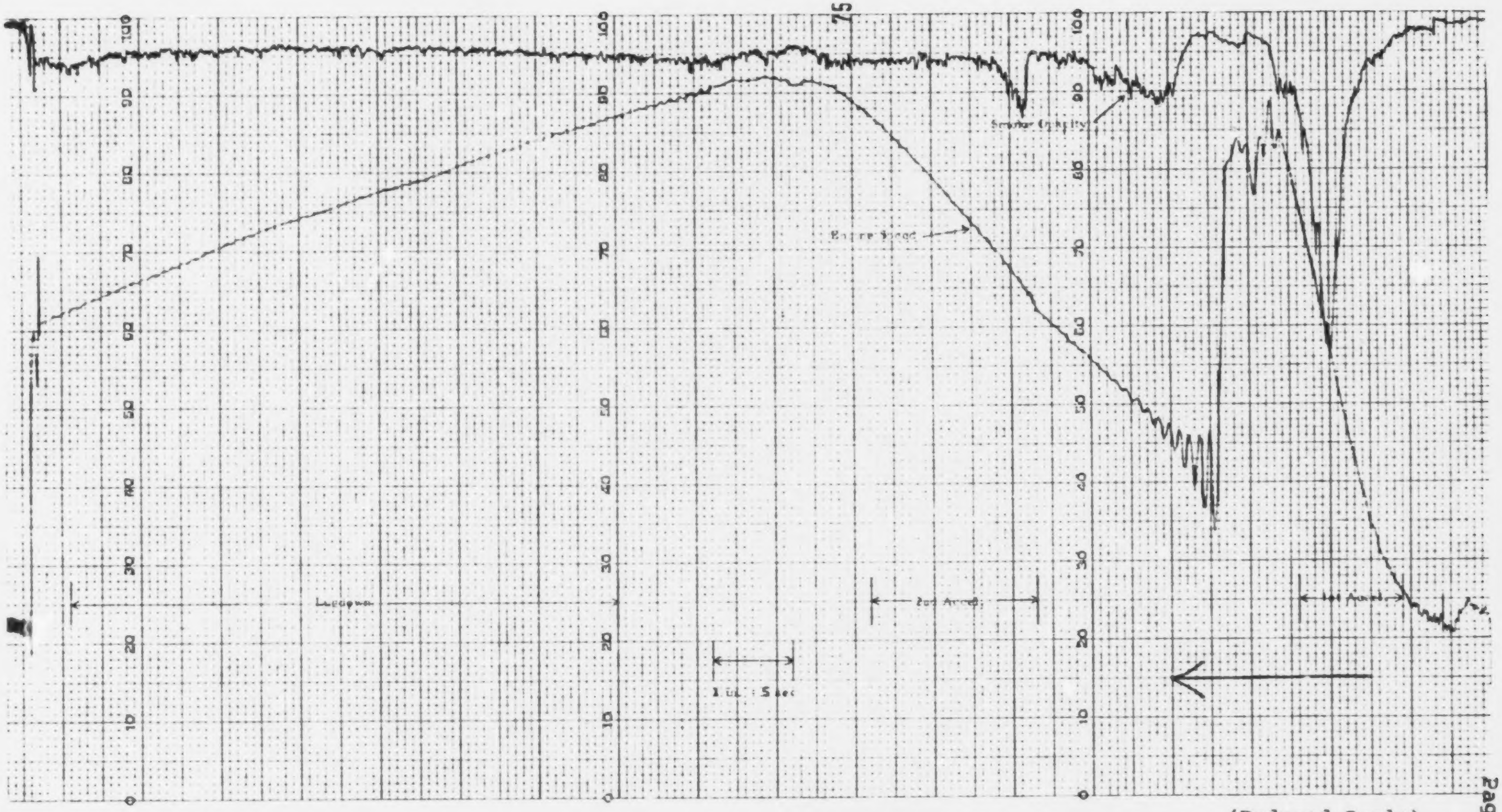
(g) Average the 15 readings of the lugging mode and designate the value as "b".

(h) The nine highest readings determined by steps (d) and (e) are averaged and designated as value "c".

In addition deterioration factors "A", "B" and "C" are also calculated as specified in Federal Register 85.874-28 using data from emission and durability engines for compliance purposes.

An example of the speed and opacity trace is shown in Figure 7-1. It is apparent from this chart, that locating the intervals manually is a difficult and tedious job. Many errors could be expected in manual reduction of the data, consequently reduction by computer integration is the preferred method.

Since the three cycles, theoretically, should result in the same value, it would be more advantageous from a validation or audit standpoint to average the cycles independently. This data would then lend itself to the establishment of a control chart to detect cycle-to-cycle changes. Excessive changes from one cycle to another would indicate a need for analysis of the system or engine to determine cause of changes and corrective action required.



(Reduced Scale)

Figure 7-1. SMOKE OPACITY AND ENGINE SPEED TRACES FROM A FEDERAL SMOKE TEST
(SOURCE: REFERENCE 7-1)

7.1.6 Computer

Computers, with their built in checks and reliability, are very useful in reducing test variability. The variety of computers used in mobile source testing ranges from "desk top" to completely automated systems. Although the computer is generally more reliable than manual operations, it is not infallible and should be periodically checked for reliability. One proven method of checking data reduction is the use of a previously prepared standard set of manually calculated data. This is fed into the computer and the output is compared with the calculated values. The same set of data could be used in cell-to-cell or laboratory-to-laboratory correlation studies.

Another source of error which may occur when using computer integration of a smoke trace is the inherent electronic noise associated with this type of instrument. The computer is usually unable to distinguish between noise and trace signal. Electronic filters are used to eliminate some of the noise but these do not completely eliminate the noise problem.

7.2 VARIABLES ASSOCIATED WITH THE MEASUREMENT OF GASEOUS EMISSIONS

The heavy duty diesel gaseous emission test begins with a warm engine which is subjected to a prescribed sequence of engine operating conditions using an engine dynamometer, with continuous analyses of the exhaust gases. The test is designed to determine the brake-specific emissions of hydrocarbons, carbon monoxide and oxides of nitrogen when an engine is operated through a cycle. The cycle consists of three idle modes and five power modes at each of two speeds which span the typical operating range of diesel engines. The procedure requires the determination of the concentration of each pollutant, the exhaust flow and the power output during each mode. The measured values are weighted and used to calculate grams of each pollutant emitted per brake horsepower hour.

The specified equations for the calculations are as follows:

1) Calculate the mass emissions for HC, CO, and NO in grams per hour for each mode as follows:

$$HC_{mass} = 0.0132 \times HC_{conc}\text{(ppm-carbon)} \times \text{exh mass (lb/min)}$$

$$CO_{mass} = 0.0263 \times CO_{conc}\text{(ppm)} \times \text{exh mass (lb/min)}$$

$$NO_{2\ mass} = 0.0432 \times NO_{conc}\text{(ppm)} \times \text{exh mass (lb/min)}$$

2) Calculate the weighted BHP, HC_{mass}, CO_{mass}, and $NO_{2\ mass}$ for each mode by multiplying the value of each by the weighting factor for that mode. THe weighting factors are 0.20 for the average idle mode and 0.08 for all other modes.

3) Calculate the brake specific emissions for HC, CO, and NO as follows:

$$BSHC = \frac{\Sigma (HC_{mass} \times WF)}{\Sigma (BHP \times WF)}$$

$$BSCO = \frac{\Sigma (CO_{mass} \times WF)}{\Sigma (BHP \times WF)}$$

$$BSNO_2 = \frac{\Sigma (NO_{2\ mass} \times WF)}{\Sigma (BHP \times WF)}$$

It is apparent from these formulas that any error associated with the measurement of the three factors involved, mass flow, pollutant concentration, and power will have a direct effect on the brake specific emissions. In addition as with any system which measures more than one component, the variability will differ for each component because of the inherent differences in the instruments and sampling characteristics.

7.2.1 Determination of Brake Horsepower

The observed brake horsepower is calculated by

$$bhp = \frac{RPM \cdot Torque}{5252} \qquad \text{(Ref. 7-2)}$$

Calibration of the speed and torque outputs are discussed in section 7.1.1. The tolerances associated with the measurement are ±50 RPM and ±2 percent of the maximum torque at the test speed. The RPM trace shall have a resolution within 30 RPM and the torque trace shall have a resolution within 10 ft.-lbs. The deviation of a reading will vary with the mode and engine horsepower. This deviation could be appreciable for determination of horsepower on the lower end of the scale.

A standard practice for reducing torque reading errors is to hang a reference weight on the torque arm prior to each test. A deviation of more than ±2 percent of calibrated reading indicates a need for recalibration of the dynamometer.

Engine speed is cross-checked using a alternate RPM meter such as a portable tachometer.

Another means of reducing reading errors would be the use of an expanded range for the lower readings.

7.2.2 Measurement of Exhaust Flow

The Federal Register references the SAE Recommended Practice No. J244 titled "The Measurement of Intake or Exhaust Flow in Diesel Engines" for the determination of Mass flow. This referenced paper proposes three separate metering systems and the associated equipment required to measure diesel engine gas flows at steady state operating conditions. Accuracy goals are established, together with procedures and equipment necessary to obtain these goals. Of the three methods, the EPA has selected for use the laminar flow element method which has an NBS traceable accuracy of ±1 percent of the true flow value. A density factor of 0.0748872 is used to convert CFM to lbs./min. Suitable tolerances for this procedure are recommended in Appendix III of the Federal Register (Ref. 7-3). A coefficient of variation of 1 percent has been established for this method from Constant Volume Sampler data (Ref. 7-4).

The mass of air thus determined is added to the mass of fuel determined directly using a fuel mass flowmeter. The primary reference standard for this type of meter is a "dead weight" type mass flow device (See TP-755 and TP-756 in Volume II). Indicated accuracies for the fuel measurement are generally ±1 percent.

7.2.3 Determination of Exhaust Emission Concentrations

Exhaust emission concentrations are determined using an analytical system calibrated with gas mixtures which have a specified accuracy of ±2 percent. Usually instrument curves are constructed with gas mixtures having accuracies of ±1 percent or better. Gravimetric standards prepared and used by the EPA have a reported accuracy of ±0.5 percent or better. In addition, reference standards are available from the NBS (SRM's 1665-1669, 1673-1675, 1677-1681, and 1683-1687). Instrument precision and reproducibility are specified by the Federal test procedure and through experience have been found to conform to these specifications when properly maintained. Successive analyses of the same sample give a precision of ±0.5 percent of the full scale concentration (Reference 7-4).

The primary sources of variability in the analytical system are:

- Accuracy of the calibration gases
- Instrument precision
- Accuracy of working or span gases
- Calibration curve construction
- Condition of the sampling system
- Full scale concentration
- Zero gas impurity
- Instrument drift (electronic)
- Operator
- HFID Fuel
- HFID sample temperature

The variables are controlled through a system of audits, performance and receiving inspection checks, etc., previously described. Detailed procedures for these appear in Volume II, the Test Procedure Manual. In the determination of the effect of error in concentration measurement, a coefficient of variation of 1 percent of the full scale is usually encountered in a repetitive determination on the same sample (Ref. 7-4). However, variation between analytical systems has been experienced as high as ±3 percent for the same sample. Correlation values in excess of this are, however, considered to be undesirable and suggest a need for corrective action. Corrective action usually involves a system leak check, reanalysis of the working gas and construction of a new instrument curve followed by a systematic check of the sources previously mentioned.

An error in the measurement of an exhaust component would obviously have a corresponding direct effect on the mass emission values. By measuring the concentration on the lowest convenient range the accuracy of the data is improved. Instrumentation with a capability of multiple range selection is available and used by many laboratories, consequently they are able to use lower ranges than those specified in the Federal Register.

Other sources which need further control are the instrument zero drift, which should be checked periodically, and the contaminants in the zero gases. Nitrogen and air zero gases should be rigorously analyzed by the receiving laboratory rather than the present practice of accepting batch analysis from the supplier.

Along with reducing contaminants in zero gas, the reduction of contaminants in laboratory ambient air concentrations should also be considered. Inspection of the heating system for leaks and proper ventilation, will all help in achieving more desirable ambient conditions.

Because of the variety of available certified accuracies for calibration gases, a decision must be made based on cost versus reliability desired when obtaining the laboratory standards and "working gases."

Naturally, as the certified accuracy of the blend is improved, the cost of the gas increases exponentially. In all cases, however, traceability to the EPA primary standards either through correlation programs or by direct analysis by EPA is necessary.

Calibration curves may be checked weekly by using the primary set of gases. However, this is a rather lengthy process involving the use of a large number of cylinders. When correct instrument maintenance procedures are complied with, the instrument curve shape generally remains stable for long periods of time. Consequently a simpler process would be to check the mid-point of the curve using a primary standard and the span for the most frequently used ranges. These results (the mid-point deflection) are plotted on control charts (Section 6) for each instrument. When an "out of control" situation is detected the complete calibration curve should be repeated and the span gas reanalyzed.

Hydrocarbon emissions from diesel engines require pre-heated sample lines and detectors because of the low vapor pressure of the hydrocarbons in the exhaust. An (SAE) recommended control temperature is 160 ±10 °C (320 ±18°F). A temperature set point control of ±2°C is desired however maintaining this throughout the sampling system for the entire 13 mode cycle is a difficult task.

If one compares the boiling ranges of the two fuels (gasoline 75-415 °F, Diesel 350-660 °F) it is readily apparent why the elevated temperature is necessary for the detection of hydrocarbons in diesel exhaust. Control of this elevated temperature is critical for both sampling efficiency and detector response. In correlation studies the temperature set point should be specified.

Another problem associated with sampling diesel exhaust is the oxygen response of the detector. A procedure for optimizing the performance and determining oxygen response is detailed in Volume II, TP-754, and SAE J215 and J1003 (References 7-5, 7-6). This problem is not encountered in light duty testing since the concentration of oxygen in the sample is close to that of air, and air diluent standards are used for calibration. These same standards are also used for heavy duty diesel engine emission testing, but the sample O_2 concentration ranges from 5 to 20 percent. If the O_2 correction is in excess of ±2 percent over this range a correction factor must be established and used. If it is in excess of 10 percent the detector or instrument should be replaced. If the correction factor is required then the uncertainty of the O_2 concentration will have an effect on the mass data.

Nitrogen oxides (NO_x) are presently being detected utilizing the NDIR instrument which is specific for NO. Nitrogen dioxide (NO_2) is not detected by this method. NO in the presence of O_2 will oxidize to NO_2. Consequently it is important when using this method to keep the sample transport time to a minimum by locating the analyzer reasonably close to the engine and using high flow rates. Future standards will most likely be based on the use of a chemiluminescence analyzer using a converter similar to those presently used in light duty testing. This would eliminate the NO - NO_2 conversion problem and the interference from other exhaust components associated with the NDIR method.

7.3 THE ENGINE AS A SOURCE OF VARIABILITY

Heavy duty diesel engines are themselves sources of variability on a test-to-test basis and during the determination of durability emission data. Emissions are known to change significantly after a break-in period and over the period of 1,000 hours of durability tests. Consequently deterioration factors are applied to the data submitted to EPA for engine certification.

Engine are affected by ambient conditions and the applied torque of the dynamometers. A reference or correlation engine should be characterized by varying the various operating parameters within the allowable operating ranges. A significant number of tests should be run to characterize the emission profile.

In addition the conditioning and soak time prior to a test are prime sources of test variability. Engine soak time must be specified with ample running time prior to soak to assure equilibrium conditions similar to those encountered in running the engine for 125 hours intervals. The Federal test procedure requires the preconditioning of a "warm" engine prior to the start of the test. The definition of a "warm" engine and a procedure for warming the engine are not specified. Better definition of this preconditioning procedure would reduce variability and improve correlation between laboratories.

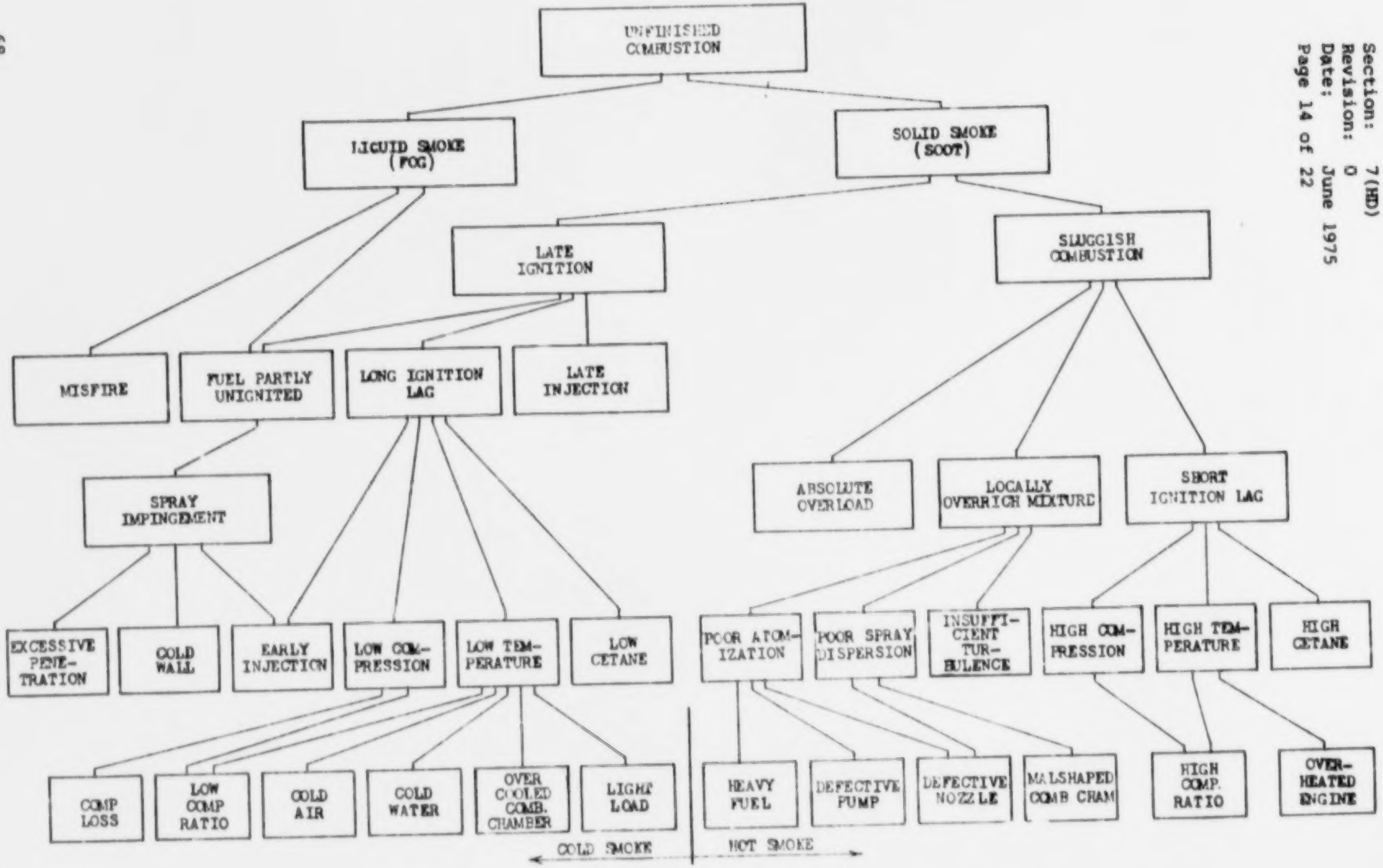
An illustration of factors which may result in diesel smoke is presented in Figure 7-2. In most cases these same factors also affect the gaseous emissions. Practically all of these factors as sources of variability cannot be controlled by emission test laboratories. Engine variables are the responsibility of the manufacturer but they do serve as a reminder that an engine installed in a test cell must be set to correct engine operating specifications in order to achieve a reliable determination of the emissions.

7.4 MEASUREMENT OF VARIABILITY IN EMISSION MEASUREMENT SYSTEMS

Variability of the measurement system is defined as the inability to achieve identical test results from repeated tests on the

Figure 7-2

FACTORS RESULTING IN SMOKE AND UNFINISHED COMBUSTION


UNFINISHED COMBUSTION
LIQUID SMOKE (FOG)
SOLID SMOKE (SOOT)
LATE IGNITION
SLUGGISH COMBUSTION
MISFIRE
FUEL PARTLY UNIGNITED
LONG IGNITION LAG
LATE INJECTION
ABSOLUTE OVERLOAD
LOCALLY OVERRICH MIXTURE
SHORT IGNITION LAG
SPRAY IMPINGEMENT
EXCESSIVE PENE-TRATION
COLD WALL
EARLY INJECTION
LOW COM-PRESSION
LOW TEM-PERATURE
LOW CETANE
POOR ATOM-IZATION
POOR SPRAY DISPERSION
INSUFFI-CIENT TUR-BULENCE
HIGH COM-PRESSION
HIGH TEM-PERATURE
HIGH CETANE
COMP LOSS
LOW COMP RATIO
COLD AIR
COLD WATER
OVER COOLED COMB. CHAMBER
LIGHT LOAD
HEAVY FUEL
DEFECTIVE PUMP
DEFECTIVE NOZZLE
MALSHAPED COMB CHAM
HIGH COMP. RATIO
OVER-HEATED ENGINE
COLD SMOKE
HOT SMOKE

Source: Schweitzer, P. H., Must Diesels Smoke? Diesel Power and Diesel Transportation March, 1947.

same engine without changes to hardware or engine adjustments specifications. Variability exists in test results to varying degrees dependent on the type of variability, test-to-test, cell-to-cell within a laboratory, or laboratory-to-laboratory.

A discussion of the importance of determining variability and its effect on the automobile manufacturers has been presented by Ford (Reference 7-7) and General Motors (Reference 7-8) in the applications for suspension of the 1977 Federal Emission Standards. As the emission requirements become lower, the level of variability significantly affects the ability to develop and certify emission control systems. Variability factors are affected not only by the vehicle, but also by the test-to-test variability. It is important, therefore, to determine the expected variability to ascertain the actual levels of exhaust emissions for certification of emission control devices. Consideration is given in these reports not only to the "in house" variability, but also to correlation factors which exist between the manufacturer's laboratory and the EPA laboratory.

Variability in emission measurement systems is usually expressed as the coefficient of variation which is defined as the standard deviation (s) divided by the mean of the results, expressed as a percentage (CV = $\frac{s}{\bar{x}}$ (100) percent). Also variability may be defined for some confidence level, for example, to assess the variability associated with a 90 percent confidence level, the standard deviation times 1.645 is added to and subtracted from the mean. For the 95 percent confidence level, 1.96 is used as a multiplier in a similar calculation. In other words, as the confidence level is increased, the confidence interval becomes wider. Therefore, in the case of a certification engine the higher the confidence level selected the more efficient the emission control system must be in order to obtain the emission values required to be statistically cconfident that all engines will meet the Federal Emissions Standards.

The Coordinating Research Council has carried out a four-phase cooperative program to evaluate techniques in measuring gaseous emissions in diesel exhaust (Reference 7-9, 7-10).

Each phase involved the measurement of diesel exhaust from a single engine either by circulating the engine among the laboratories or by all participants measuring emissions on the same engine at the same time. In the fourth phase of the program a multicylinder diesel generating set was circulated among 15 participating laboratories each using the same procedure recommended by the Society of Automotive Engineers (J215). In addition to the engine, unknown gas mixtures were also circulated among the laboratories. Analysis for hydrocarbons were fairly consistent within laboratories both on unknown gas mixtures and engine exhaust, with coefficients of variation of 3 percent and 10 percent respectively. However, analysis differed substantially among laboratories both on gas mixture and exhaust with coefficient of variations of 10 percent and 22 percent respectively. The data are presented in Tables 7-2 and 7-3. There is an indication of need for further improvement in techniques for analyzing diesel exhaust hydrocarbons, and especially in the analysis of unknown gas mixtures. With the availability of gas mixtures with accuracies of better than ±2 percent a coefficient of variability in the area of 2-4 percent would be expected.

The results for CO and NO were reported for idle, mid-power and high-power and appear in Tables 7-4 and 7-5. Coefficient of variations (CV) reported for CO were - Idle 5.7, Mid-power 9.0 and High-power 24 percent. For NO the reported CV's were-Idle 16, Mid-power 13 and High-power 7.9. This data also indicates a need for improvement especially in High-power CO mode.

Futher test details and data analyses are contained in the referenced data and associated CRC reports. The development and improvement of procedures for future heavy duty emissions measurements are presently being accomplished at the EPA, Ann Arbor facility. Identification of specific details of these test procedures and associated instrumentation will aid in reducing the present interlaboratory test variability.

7.5 QUALITY ASSURANCE AND TEST VARIABILITY

Statistical methods that can be used to control test variability have been described extensively in Section 6. Quality Assurance has the responsibility for controlling the test-to-test variability and improving data reliability. Many studies have been done on methods of reducing test variability. However, further reduction of test variability is impractical in many cases; consequently Quality Assurance should advocate the use of procedures such as data validation, calibrations, and maintenance, and assure that these procedures are being complied with. Tables 7-6 and 7-7 are summaries of the test variables and the methods used for their control.

Many of the precautions and checks mentioned in this section are included in the Test Procedures (Volume II). Each test facility, depending upon its experience and judgment should carefully review this section to determine if some or all of the additional precautions and checks should be introduced as routine or periodic checks into their operational test procedures.

Test facilities should continually record and assess variabilities from various sources within the test system in a systematic summary. Periodic review of variability and comparisons with data from other facilities will indicate which sources of variability have priority for reduction efforts.

Table 7-2. PARTICIPANTS' ANALYSES OF BOTTLED GASES

	HYDROCARBON CONCENTRATION, ppm C			
	Cylinder No. 1		Cylinder No. 2	
Laboratory No.*	Average	Range	Average	Range
1	283	36	2128	140
2a	307	7	2284	45
2b	308	8	2235	160
3	304	30	2378	40
4	328	9	2390	22
5	304	3	2221	20
6	319	22	2357	13
7	290	22	2340	64
8	228	3	1613	10
9	-	-	-	-
10	-	-	-	-
11	284	3	2210	20
12	253	5	1898	63
13	327	8	2323	39
14	282	9	2175	84
15	318	9	2412	30
16(3)	292	7	2350	80
Average	295		2221	
Range	99(34%)**		799(36%)**	
Standard Deviations				
Pooled Within Laboratories	8(3%)**		36(2%)**	
Of Laboratory Averages	27(9%)**		212(10%)**	

*Laboratory 2 used two analyzers, identified as (a) and (b). Laboratory 16 is the same as Laboratory 3; it is identified separately because of the lapse in time between the two sets of tests.

**( ) indicates % of mean value.

(Reference 7-9, 7-10)

Table 7-3. ANALYSES OF ENGINE EXHAUST

	HYDROCARBON CONCENTRATION, ppm C					
	Idle		Mid Power		Full Power	
Laboratory No.	Average	Range	Average	Range	Average	Range
1	330	24	188	61	204	40
2a	847	55	468	54	343	55
2b	874	90	409	68	280	23
3	709	130	413	110	319	45
4	720	135	371	130	292	14
5	606	39	398	63	560	162
6	1024	150	448	123	330	116
7	696	132	390	112	340	92
8	631	135	325	90	254	103
9	552	40	300	156	246	84
10	814	126	510	190	427	69
11	753	111	485	246	381	128
12	628	95	394	125	338	90
13	754	26	432	68	398	49
14	813	48	412	78	272	15
15	494	119	266	53	247	80
16(3)	672	83	432	142	454	78
Average	701		391		334	
Range	694(99%)		322(82%)		356(106%)	
Standard Deviations						
Pooled Within Laboratories	46(7%)		57(15%)		35(11%)	
Of Laboratory Averages	158(22%)		75(19%)		88(27%)	

(Reference 7-9, 7-10)

Table 7-4. ENGINE TEST RESULTS CARBON MONOXIDE, ppm

PARTICIPANT NUMBER		IDLE*	MID-POWER*	HIGH-POWER*
1		495	437	759+
2		563	505	400
3		551	463	311
4		498	435	372
5		~~266~~+	194	159
6		541	410	286
7		561	450	382
8		586	494	544
9		559	485	470
10		~~448~~+	501	530
11		565	~~622~~+	615
12		576	551	~~692~~+
13		561	483	469
14		518	546	~~905~~+
15		601	~~792~~+	~~1197~~+
16		526	~~358~~+	375
$\bar{x}$		550	480	432
Range, ppm	Hi	601	551	615
	Lo	495	410	286
	%	19	29	76
Standard Deviation,	ppm	31	43	102
	%	5.7	9.0	24

*Average Value, 4 runs.
+Value Dropped.

(Reference 7-9, 7-10)

Table 7-5. ENGINE TEST RESULTS NITRIC OXIDE, ppm

PARTICIPANT NUMBER	IDLE*	MID-POWER*	HIGH-POWER*
1	-	-	-
2	84	525	1287
3	95	660	1365
4	78	502	1178
6	109	554	1240
7	68	511	1179
8	75	475	1044
9	95	546	1220
10	70	463	1186
12	138	571	1065
13	86	538	1150
14	68	485	878
15	73	387	645
16	96	573	1103
$\bar{x}$	83	522	1183
Range, Hi	109	660	1365
Lo	68	387	1044
%	49	52	27
Standard Deviation, ppm	13	66	94
%	16	13	7.9

*Average Value, 4 runs.

(Reference 7-9, 7-10)

Table 7-6. SUMMARY OF SMOKE EMISSION TEST VARIABLES AND METHODS USED FOR THEIR CONTROL

TEST VARIABLE	METHOD USED TO CONTROL TEST VARIABLES													
	Calibration	Ref. Standards	Data Validation	Daily Checks	Monthly Checks	Maintenance	Training	Audit	Preconditioning	Correlation	Control Charts	Receiving Insp.	Instrument Range	Environmental Control
Dynamometer	x	x	x	x	x	x	x	x			x			
Engine						x	x		x	x		x		x
Smoke Meter	x	x				x	x			x	x	x		x
Drift			x	x		x		x						x
Noise			x	x		x								
Linearity	x		x	x				x						
Calibration		x		x										
Recorder	x				x	x		x						x
Temperature	x	x	x	x		x		x		x		x		x
Barometer	x	x	x	x		x		x		x		x		x
Humidity	x	x	x	x		x		x		x	x	x		x
Data														
Charts	x		x				x	x			x			
Computer	x		x	x			x	x						

Table 7-7. SUMMARY OF GASEOUS EMISSION TEST VARIABLES AND METHODS USED FOR THEIR CONTROL

TEST VARIABLE	METHOD USED TO CONTROL TEST VARIABLES													
	Calibration	Ref. Standards	Data Validation	Daily Checks	Monthly Check'	Maintenance	Training	Audit	Preconditioning	Correlation	Control Charts	Receiving Insp.	Instrument Range	Environmental Control
Brake Horsepower														
Torque	x	x	x	x	x	x		x					x	
RPM	x	x	x		x	x		x					x	
Air Flow (LFE)		x	x		x	x	x			x				
Fuel Flow	x	x	x	x	x	x	x	x		x				
Calibration Gases		x			x			x		x		x		
Instrument	x			x	x	x	x	x		x			x	
Span Gas	x	x	x	x	x						x		x	
Sample System				x	x	x	x	x						x
Zero Gas		x								x	X	x		
HFID Fuel		x										x		
Operator							x	x			x			
Engine				x		x	x	x	x	x		x		x

Section 8

QUALITY ASSURANCE SYSTEM (ON-SITE) SURVEY

The greatest drawback to effective quality assurance is the failure to provide well developed quality assurance plans and procedures. Actual proof of a system's effectiveness lies in determining how the plans and procedures are converted to the required physical action. This can be accomplished by means of a system survey. The evaluation of a mobile source emission testing facility quality assurance system by means of a survey is discussed in this section.

8.1 GENERAL REQUIREMENTS

A Quality Assurance system survey must be able to pin-point quality system failure problems and provide a positive system for corrective action and follow-up procedures. With effective follow-up procedures, corrective action becomes the "closed loop" feature in the systems survey cycle. To ensure that test facilities have the capabilities of meeting quality assurance requirements they must adequately demonstrate their acceptability during a survey and review of their management organization, facilities, personnel, procedures and data systems.

Surveys are usually performed by a team from quality assurance and engineering. If the results of the survey are related to a very important pending or actual contract purchasing may need to be involved. (Teams composed of personnel experienced in only certain areas, but who, as a group, meet all the necessary qualifications, may be used.) Surveys can be performed by a single individual provided he has a thorough knowledge of, and sufficient experience in, investigating and assessment of all areas and facets of quality assurance systems, and mobile source emission testing.

The survey is specifically designed for a test facility conducting emission tests on mobile sources. Its use, however, is not limited to evaluation of those laboratories conducting emission tests for the EPA. It may be used by any test facility for self-evaluation or by any organization such as an emission device or engine manufacturer purchasing testing services from independent testing laboratories.

Prior to traveling to a test facility the survey team should research the facility's quality history data, and seek pertinent information from purchasing, test and quality engineering to determine the facility's current status. The survey team should hold a preliminary meeting to discuss the survey plan.

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The survey checklist should not be regarded as a panacea for quality system evaluation. It is a device used to assure a systematic look at the important areas. The investigator must ask for and see objective evidence of each aspect of items on the checklist. The results of the checks and other observations may lead the investigators to survey an area not specifically covered in the checklist. Comments concerning these other areas should be recorded in the "Remarks" section of the survey report to assist in the final evaluation. The Department of Defense has provided a detailed handbook on the evaluation of a contractor's quality program, however, many requirements are more restrictive than are warranted in mobile source emission testing (Reference 8-1).

It is sometimes said that some facilities are too small to have a quality assurance system. However, smallness is no excuse for lack of control. Obviously many small facilities do not need a full time quality assurance representative, or require the imposition of elaborate controls. Those conducting the survey may elect to de-emphasize certain areas such as procurement controls and incoming material inspection requirements, if previous experience with the facility, or the particular activities at the facility warrant it. In contrast, if the survey is in connection with the award of an important service contract, then strict adherence with respect to all portions of the survey would be necessary.

8.2 ADMINISTRATION GUIDELINE QUALITY ASSURANCE SYSTEM SURVEY REPORT

The Quality Assurance System Survey Report consists of two sections, (i) a cover sheet containing general information and the end results of the survey, (ii) a detailed survey checklist covering the various elements of a Quality Assurance system for mobile source emission testing facilities.

Each Survey Report should be assigned a separate identification number for administrative traceability. This information is entered in the top right hand corner of the cover sheet, together with the date of survey and an indication as to whether it is the first survey or a re-survey.

The cover sheet briefly describes the location of the facility being surveyed, identifies who is responsible for the Quality Assurance functions, indicates the organizational structure of the facility, the proportion of personnel in testing, engineering and quality assurance and identifies the personnel contacted during the survey. The investigator should also indicate who requested the survey and the contract/P.O. number if applicable.

The survey should not consist of merely asking questions. The investigator should request visual proof of how the system works. In evaluating the various audit elements, three alternative decisions are available to the investigator, (i) Acceptable (A), (ii) Conditional Acceptance (C), (iii) Unacceptable (U). Further amplification of these decisions can be made in the "Remarks" space on the last page of the checklist. The following guidelines, listed in the same sequence as the system elements on the checklist, will assist the investigator in evaluating the Quality Assurance system.

A. Organization

1. "Organizational authority of quality assurance." Does the established system identify the organizational element responsible for quality assurance? Do the personnel performing the quality functions have sufficient authority, responsibility and freedom of action to identify and evaluate quality problems and initiate, recommend, or provide solutions? Verify that there is one individual who has overall responsibility for quality assurance in the organization.

2. "Documentation of quality system requirements." Are documented procedures available and used for all testing and laboratory operations which affect quality? Ask to see copies. Are procedures reviewed on a systematic basis to assure accuracy, completeness and operator/analyst compliance? Do supervision and quality assurance personnel make proper use of procedures? Verify that procedures are available for all routine operations (receiving, assembly, test, sampling, calibration, analysis, etc.). Review for current status, control, and availability on a "need to know" basis.

3. "Issue of activity and audit reports to management, listing deficiencies and corrective action taken." Are reports sent to management highlighting quality problems and corrective action taken to alleviate those problems? Verify that activity, and independent performance audit reports initiated by quality assurance are sent to top level management. Ask to see a copy of the latest report.

B. Procurement Control

1. "Imposition of quality requirements on procurement orders." Review ordering documents to assure that the laboratory includes quality assurance and acceptance provisions for all procured items such as testing services, equipment,

calibration and zero gases, fuel, etc., directly affecting the quality of laboratory testing or results of testing. Do the procurement orders require test reports or certifications? Does the person responsible for quality assurance review the procurement orders? Ask to see the procurement order file. Emphasis should be placed on the selection of suppliers, pre-planning the requirements from the supplier, and the maximum utilization of supplier data and quality information with a corresponding minimization of incoming inspection requirements.

C. Incoming Material Inspection

1. "Availability of acceptance standards and procedures in receiving inspection area." Go to the receiving inspection area and ask to see some acceptance procedures. Determine if they are current, useful and appropriate.

2. "Maintenance of inspection records on all items received." Review receiving records to assure that inspection acceptance/rejection data are being maintained for all procured items directly affecting the quality of emission testing or results of testing. Does quality assurance inspect supplier's material to the extent necessary upon receipt?

3. "Segregation and identification of non-conforming supplies." Verify that non-conforming fuels, chemicals, gases, equipment and components are positively identified and segregated in a manner which prevents contamination of accepted lots. How is it identified? Where is it stored while awaiting disposition? Go and look at it.

4. "Indication of inspection status on all supplies." Verify that the inspected items are stamped, tagged or otherwise identified as to their acceptance/rejection. Identifying stocks of fuel, chemicals, gases, etc., and keeping uninspected, untested/rejected material separate from that already inspected, tested/accepted must be done very carefully. The inadvertent issue of wrong or defective material can be disastrous.

5. "Verification of certified fuels, chemicals and gases by chemical/physical analysis on established frequencies." Review chemical/physical test reports provided by suppliers of fuels, chemicals and gases to determine if suppliers periodically perform verification tests to validate test reports and certifications. Review results of verification tests to assure that constituents are correctly stated on test reports and certifications and that they conform with applicable EPA specifications.

6. "Verification of performance testing, functional testing and calibration of procured equipment." Verify that records are maintained as objective evidence of performance and functional testing of procured equipment and that the equipment has been calibrated correctly.

7. "Identity and storage of limited life items." Verify that all limited life items have the date of manufacture or receipt of the items clearly marked on their containers. They should be stored in such a manner that they can be used in order of receipt and thus spend minimum time in storage, and are not to be used beyond their expiration date.

8. "Maintenance of a system for obtaining corrective action from suppliers." Verify that there is a system for obtaining supplier corrective action. Ask to see a recently completed request for corrective action from a supplier.

D. Calibration of Inspection and Test Equipment

1. "Written description of calibration system covering measuring and test equipment." Request a copy of the laboratory's written description of its calibration system and audit program for maintaining correctly calibrated equipment. Emphasis should be placed upon maximum utilization of equipment manufacturer calibration methods or standard calibration methods prescribed by A.S.T.M., S.A.E. and Federal Register procedures, rather than an invented method of the user.

2. "Provision for the calibration of measuring and test equipment at periodic intervals." Determine that realistic calibration intervals are assigned for measuring and test equipment, and that they are established on the basis of stability, purpose and degree of usage.

3. "Maintenance of calibration records on all measuring and test equipment". Verify that adequate calibration records are maintained to identify and categorize each item of measuring and test equipment. Adequate records would include history of the item, its accuracy, present location, calibration interval and when due, calibration procedures and controls necessary, actual values of latest calibration and inventory of maintenance and repair made.

4. "Validity of calibration decals/labels." Verify that calibration decals/labels are affixed to each item of measuring and test equipment, indicating the date of last calibration, by whom, and the date when next calibration is due. Ask to see a master list of all equipment on the calibration schedule, select some items at random from both the receiving inspection and testing areas, and visually check the selected items for current calibration decal/label.

5. "Availability of calibration traceability to NBS/EPA." Select certifications of several reference standards and determine if they are traceable to the Standard Reference Materials prepared by the NBS, or the EPA Primary Governmental Standards. Do calibration sources other than the National Bureau of Standards or a government laboratory have their standards compared with a National standard at planned intervals? Are secondary standards or working gases referenced or analyzed against these primary standards?

6. "Imposition of requirement on suppliers to have a system which assures accuracy of their measuring and test equipment." Verify that the laboratory has taken action to assure the accuracy of test and measuring equipment used by its suppliers. Are the limits of impurities and analytical tolerances specified by their purchase orders? Are analytical methods referenced or defined? Are calibration methods defined such as NBS, ASTM, etc?

E. Engine Testing

1. "Provision of applicable inspection and test documents." Request copies of procedures covering the engine testing performed by the laboratory. Verify that the prescribed procedures are not in conflict with Federal Register requirements. Verify that the tests are conducted in accordance with the written test procedures by observing the technicians performing the test. Request and observe certain calibrations of the test equipment. Give techniciane oral quiz using the written procedure for the source of items to determine his familiarity with documented procedures.

2. "Availability of documented test procedures, adequate test equipment and appropriate work environment." Verify the use of documented test procedures, the specification of adequate test equipment and a suitable work environment. Request a copy of a recently issued test procedure.

3. "Provision of acceptable/unacceptable criteria for each test measurement." Review the inspection/test procedures and data recording forms for inclusion of acceptance/rejection criteria.

4. "Accomplishment of testing in accordance with test specifications and procedures." Witness a test to determine if laboratory is accomplishing and reporting the testing in accordance with the test procedures.

5. "Application of corrective measures when non-compliance occurs." Verify the use of a prompt, effective corrective action system. Is there an adequate form in use for requesting corrective action? Who initiates a request for corrective action? Who determines the adequacy of corrective action? Do corrective action statements include the cause of rejection and the action taken to prevent its recurrence? What follow-up methods are employed?

6. "Indication of current calibration status on test equipment." Check items of test equipment to assure that they have current calibration decals, stickers or tags affixed, and are in good working condition. Visual check equipment for cleanliness, apparent damage and/or malfunction.

7. "Maintenance of controlled conditions as required for testing sequences." Witness a test and verify that conditions are controlled and maintained as specified in the test specifications/procedure.

8. "Issue of reports to engineering on test and inspection problems or deficiencies." Request and review a copy of a recent report issued to inform engineering on problems or deficiencies in inspection or testing. Is there an adequate form used for this report?

9. "Documentation, reinspection and retest of instruments and equipment reworked, repaired or modified after testing." Review inspection/ test records to verify that instruments and equipment reworked, repaired or modified due to a malfunction during an engine test are reinspected and tested prior to being placed back in service again. Review inspection/test records to verify that repairs or modifications made to an engine are adequately documented and reported.

10. "Maintenance of accurate and complete test results and data, with traceability to the tested engines and the test and measuring equipment used." Review records of data and test results. The records should show evidence of configuration control and clear traceability back to the tested engine and test cell equipment.

F. General

1. "Provision of qualified testing personnel and a training and certification program for personnel involved in testing." Verify the existence of a written, established training program for personnel involved in testing, analysis, and quality assurance. Check for records of individual training history and evidence of periodic personnel testing and applicable test results.

2. "Maintenance of housekeeping and facilities commensurate with testing requirements." Check for evidence of poor housekeeping practices and determine if facilities are commensurate with testing requirements.

3. "Maintenance of a quality data reporting and analysis system, with built-in validation checks for accuracy, precision and completeness." Verify the existence of (a.) written procedures, forms, etc., used in performing necessary computations, data reductions and validations, (b.) an audit program to verify data accuracy (c.) the application of statistical quality control chart techniques if appropriate, and (d.) the reporting of the quality of the data and test results to top management on a periodic basis.

4. "Issue of inspection stamps, calibration decals, etc., controlled by quality assurance." Verify that quality assurance maintains records on the issue and control of inspection stamps, calibration decals, etc., including date of issue, reference number and recipient information.

5. "Maintenance of a configuration control system to account for changes in equipment/ documents." Verify that configuration control procedures exist and include the following provisions.

   (a) Removal of all obsolete equipment/documents from affected departments

   (b) Distribution of all new or revised equipment/documents to affected departments

   (c) Recording of point at which changes become effective

   (d) Maintenance of a master index to reflect all document issues and revisions

   (e) Review of documents/specifications prior to release

   A testing laboratory would be principally concerned with configuration accounting to assure that all similar equipments have the same configuration and that all document changes, including computer programs have been recorded.

6. "Maintenance of a quality cost system." Determine if the testing laboratory has developed specific cost data to identify prevention, appraisal, internal and external failure costs, and the effective use of this data in quality management.

7. "Provision of reliability and preventive maintenance requirements." Verify the existence of written, established procedures pertaining to reliability and preventive maintenance. The consideration of reliability and preventive maintenance in air pollution measurement is becoming increasingly important due to the complexity and sophistication of sampling, measurement, and automatic recording systems.

Upon completion of the survey the investigator/survey team evaluates the checklist and other observations noted during the survey, and discusses the findings with the interested laboratory management personnel to clarify any differences as to the facts. If the survey is of an informal nature, the approval/disapproval recommendations may be dispensed with. For a formal survey, once the facts are established the investigator indicates approval, conditional approval or disapproval in the appropriate box on the cover sheet. If conditional approval is granted, time should be allowed for correction of noted deficiencies in establishing the re-survey date. The investigator notes any specific system weaknesses that require corrective action in the space assigned for "Remarks", also any other comments pertaining to the survey, signs name in the bottom left hand box under "Survey performed by". The completed survey is routed to the investigator's departmental supervisor for approval, prior to distribution.

The report is then sent to the surveyed laboratory with request or suggestions for improvement of their quality assurance/testing program. Usually one member of the survey team is requested to follow-up after the laboratory has communicated in writing that the suggested changes/improvements have been complied with. A laboratory which has been disapproved should be allowed to request a new survey after a certain time period if they can show that a corrective action program has been implemented and completed.

8.3 Quality Assurance System Survey Report (see attached).

QUALITY ASSURANCE SYSTEM SURVEY REPORT

Survey No.______________

Date of Survey___________

Type of Survey ☐ Initial

☐ Resurvey

Laboratory Name____

Street Address____

City______________ State______________ Zip Code__________ Phone No. __________

Name of person responsible for quality assurance functions at above address.

Name____________________ Title____________________

This firm is: ☐ Independently Owned & Operated ☐ Subsidiary

Parent Organization:

☐ Affiliate ☐ Division of

Number of Personnel: Testing_____ Engineering_____ Quality Assurance_____

Personnel Contacted	Title

Survey Requested by:

Name__________________ Dept.________ Div.________ Date______________

Contract/P.O. Number ______________

Results of Survey: ☐ Approved ☐ Conditional Approval ☐ Disapproved

Resurvey Date (For use with conditional approval only)______________

REMARKS:

Survey Performed By:	Approved:	Department:	Date:

QUALITY ASSURANCE SYSTEM SURVEY CHECKLIST

Survey No. ________

A - Acceptable   C - Conditional Acceptance   U - Unacceptable

Survey Element No.	Requirements	A	C	U
A	ORGANIZATION			
1	Organizational authority of quality assurance			
2	Documentation of quality system requirements			
3	Issue of activity and audit reports to management, listing deficiencies and corrective action taken			
B	PROCUREMENT CONTROL			
1	Imposition of quality requirements on procurement orders			
C	INCOMING MATERIAL INSPECTION			
1	Availability of acceptance standards and procedures in receiving inspection area			
2	Maintenance of inspection records on all items received			
3	Segregation and identification of non-conforming supplies			
4	Indication of inspection status on all supplies			
5	Verification of certified fuels, chemicals and gases by chemical/physical analysis on established frequencies			
6	Verification of performance testing, functional testing and calibration of procured equipment			
7	Identity and storage of limited life items			
8	Maintenance of a system for obtaining corrective action from suppliers			

QUALITY ASSURANCE SYSTEM SURVEY CHECKLIST

Survey No. ________

A - Acceptable C - Conditional Acceptance U - Unacceptable

Survey Element No.	Requirements	A	C	U
D	CALIBRATION OF INSPECTION AND TEST EQUIPMENT			
1	Written description of calibration system covering measuring and test equipment			
2	Provision for the calibration of measuring and test equipment at periodic intervals			
3	Maintenance of calibration records on all measuring and test equipment			
4	Validity of calibration decals/labels			
5	Availability of calibration traceability to NBS/EPA			
6	Imposition of requirement on suppliers to have a system which assures accuracy of their measuring and test equipment			
E	ENGINE TESTING			
1	Provision of applicable inspection and test documents			
2	Availability of documented test procedures, adequate test equipment and appropriate work environment			
3	Provision of acceptable/unacceptable criteria for each test measurement			
4	Accomplishment of testing in accordance with test specifications and procedures			
5	Application of corrective measures when non-compliance occurs			
6	Indication of current calibration status on test equipment			

QUALITY ASSURANCE SYSTEM SURVEY CHECKLIST

Survey No. ________

A - Acceptable C - Conditional Acceptance U - Unacceptable

Survey Element No.	Requirements	A	C	U
E	ENGINE TESTING (Continued)			
7	Maintenance of controlled conditions as required for testing sequences			
8	Issue of reports to engineering on test and inspection problems or deficiencies			
9	Documentation, reinspection and retest of instruments and equipment reworked, repaired or modified after testing			
10	Maintenance of accurate and complete test results and data, with traceability to the tested engines and the test and measuring equipment used			
F	GENERAL			
1	Provision of qualified testing personnel and a training and certification program for personnel involved in testing			
2	Maintenance of housekeeping and facilities commensurate with testing requirements			
3	Maintenance of a quality data reporting and analysis system, with built-in validation checks for accuracy, precision and completeness			
4	Issue of inspection stamps, calibration decals, etc., controlled by quality assurance			
5	Maintenance of a configuration control system to account for changes in equipment/documents			
6	Maintenance of a quality cost system			
7	Provision of reliability and preventive maintenance requirements			

REMARKS: (Attach additional sheets if required. Identify with S/N of this report)

Section 9

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Appendix A-1

SELECTED STATISTICAL TECHNIQUES AND NOMENCLATURE

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Appendix A-1

SELECTED STATISTICAL TECHNIQUES AND NOMENCLATURE

Initially an understanding of certain technical terms is necessary in discussing statistical methodologies recommended for use. The following concepts provide the tools and definitions necessary to complete statistical analyses. (References 6-2, 6-4)

- Statistical Quality Control - A regulatory process through which actual quality performance is measured using quantitative, statistical methodologies.

- Central Tendency Measures - These measures are used to describe the value about which data tend to cluster. Examples of central tendency measures are the arithmetic mean, geometric mean, mode and median.

- Arithmetic Mean - This is the most frequently used measure of central tendency and is defined as the sum of the observed values divided by the number of observations, i.e.,

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \ldots + x_j}{n} = \frac{\sum_{j=1}^{n} x_j}{n}$$

where x_j = observed performance values
n = number of observations

- Median - The median of a set of numbers arranged in order of magnitude (i.e., in an array) is the middle value if there is an odd number of values in the set, or the arithmetic mean of the two middle values if there is an even number of values in the set.

- Mode - The mode of a set of numbers is that value which occurs with the greatest frequency.

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- Random Variable - A quantity that has a definite value for each possible result of an experiment. These values may be thought of as outcomes, e.g., instrumentation readings. Although the random variable values are unknown prior to the outcome of a reading, the probability that the random variable will take on specific values may be known in advance, as prescribed by a frequency distribution.

- Frequency Distribution - In summarizing data, it is useful to distribute data into categories and to determine the number of individuals, e.g., measurement values, belonging to each category. A tabular arrangement of data by category together with the corresponding frequency with which each value occurs is called a frequency distribution.

- Normal Distribution - A bell-shaped distribution specified by the function:

$$P = \frac{1}{\sigma_x\sqrt{2\pi}} e^{-(x-\mu_x)^2/2\sigma_x^2}$$

Where P stands for the ordinate of the normal probability distribution, and σ_x and μ_x are the standard deviation and mean of the distribution of x values and $\pi = 3.14159$ and $e = 2.71828$ are constants.

- Variance - A measure of the scatter of observations around the mean. The variance of the population and of a sample are σ^2 and s^2 respectively, i.e.,

$$\sigma^2 = \frac{1}{N}\sum_{j=1}^{N}(x_j - \mu)^2, \quad j = 1,2,3,\ldots N$$

Where σ^2 = variance of population

x_j = observed values

μ = population mean

N = Number of observations in total population

$$s^2 = \frac{1}{n-1}\sum_{j=1}^{n}(x_j-\bar{x})^2 \quad , \quad j = 1,2,3,\ldots n$$

Where s^2 = variance of sample

x_j = observed values

$\bar{x}$ = sample mean

n = number of observations in the sample

- Standard Deviation - A measure of the variation of individual observations about the mean. The unit of measurement for the standard deviation is the same as that for the individual observations. The standard deviation (equal to the square root of the variance) is referred to as σ and s for the population and a sample respectively.

- Bernoulli Trials - Describes the conditions which must be met before using the binomial distribution, which can establish QA acceptance criteria. The conditions are:

  1. Results of "trial" (e.g., selection of sample) must be totally separate of any other outcome (i.e., the outcomes cannot be related in any way).

  2. Only two outcomes of the trial exist (e.g., either pass or fail, heads or tails, etc.).

  3. The probability of a given outcome of a trial must remain constant throughout the sequence of the trials.

  4. The trials are statistically independent (i.e., the outcome of a given trial does not depend on that of another trial).

- Binomial Distribution - A family of probability distributions describing the probabilities of possible experimental outcomes for all possible experimental outcomes for all possible combinations of n trials and p, the probability of an outcome during a trial. The distribution is given by:

$$P(r/n,p) = \frac{n}{r!\ (n-r)!}\ p^r(1-p)^{n-r}$$

Where r = actual number of specific outcomes during a sequence of trials

n = number of trials in the sequence

p = probability of a given outcome's occurrence during sequence of events

Such a distribution is important in that it forms the basis for much of the QA acceptance sampling theory. It is possible to compute mathematically the probability that a lot of a given percentage defective (e.g., the number of automobiles above certain prescribed exhaust emission levels) will be accepted under a given sampling plan.

- Random Error - Inaccuracies due to small, indeterminate variations in a system's performance. The distribution of random error is usually assumed to be normal, i.e., Gaussian, with a mean equal to zero.

- Range - The difference between the maximum and minimum values for a sample of observed values. When the number of observed values is small, the range is a relatively sensitive measure of general variability. As the number of observations increases, the efficiency of the range (as an estimator of the standard deviation) decreases rapidly.

- Coefficient of Variation - The ratio of the standard deviation to the mean, also referred to as the relative standard deviation. It is usually expressed as a percentage and is given by:

$$CV = \frac{s}{\bar{x}} (100)\%$$

Where s = standard deviation of a sample

$\bar{x}$ = mean of a sample

- Confidence Levels - The probability that an assertion is correct about a characteristic of a measurement system.

- Confidence Interval - A statistic (e.g., the mean $\bar{x}$) is computed from the data for a sample. The statistic is then used as a point estimate of the population parameter (e.g., the mean μ). It is recognized that the statistic computed from a second sample would not be identically equal to that for the first sample. Because of this, points A and B are determined such that it can be said with a specified probability that the interval described by A and B contains the true value of the population parameter.

For example the probability statement for the 95 percent confidence interval estimate of the population mean is given by:

$$P_r\left(\bar{x} - \left(\frac{t_{n-1}s}{\sqrt{n}}\right) < \mu < \bar{x} + \left(\frac{t_{n-1}s}{\sqrt{n}}\right)\right) = 0.95$$

Where $\bar{x}$ = sample mean

s = sample standard deviation

t_{n-1} = student "t" value for n-1 degrees of freedom

n = number of observations in the sample

The probabilities usually associated with confidence interval estimates are 90, 95, and 99 percent. For a given sample size, the width of the confidence interval increases as the probability increases.

- Confidence Limits - The end points of the confidence interval A and B as discussed above, whereas:

$$A = \bar{X} - \frac{t_{n-1}s}{\sqrt{n}}$$

$$B = \bar{X} + \frac{t_{n-1}s}{\sqrt{n}}$$

- Sample - A set of objects or things from a larger set called the "population." The objects or things may be physical such as specimens for testing or they may be data values representing physical samples, or data values from a larger set of data values. Unless otherwise specified, all samples are assumed to be random samples.

- Random Samples - Samples obtained in such a manner that all items of the lot or population have an equal chance of being selected in the sample.

- Stratified Sample - (Stratified Random Sample) - A sample of the various portions which have been obtained from identified subparts or subcategories (strata) of the total lot or population. Within each category of strata, the sampling would be taken randomly. The objective of taking stratified samples is to obtain a more representative sample than that which would otherwise be obtained by a completely random sampling. The idea of identifying the subcategories or strata is based on knowledge or suspicion, or precaution against differences existing between the strata for the characteristics of concern.

- Representative Sample - A sample taken to represent the universe or population as accurately and precisely as possible. A representative sample may be either a completely random sample or a stratified sample depending upon the objective of the sampling and the conceptual or actual population for a given situation.

- Acceptance Sampling - Sampling inspection in which decisions are made to accept or reject the total population from which the sample is taken or for which the sample represents. The science that deals with the procedures by which decisions to accept or reject are based on the results of the sample inspection.

- Audit (General) - A random check to determine the quality of operation of some function or activity. Two types of audits are used in Quality Assurance: (1) performance audits, and (2) system surveys.

- Performance Audit - Planned independent (duplicate) sample checks of actual output made on random basis to arrive at a quantitative measure of the output from all or part of the total system.

- System Survey - A systematic on-site qualitative review of facilities, equipment, training, procedures, recordkeeping, validation, and reporting aspects of a total (quality assurance) system to arrive at a measure of the capability and ability of the (quality assurance) system. Even though each element of the system survey is qualitative in nature, the evaluation of each element and the total may be quantified (scored) on some subjective basis.

- "t" Distribution - A probability distribution developed by W. S. Gosset (writing under the pseudonym "Student") used in the computation of confidence interval estimates when the population standard deviation is unknown. In such a case s (the sample standard deviation) is used as an estimate of μ . When the sample size is small the value of "t" for a given probability level differs significantly from the "z " value for the normal distribution. For example, in determining the 95 percent confidence interval estimate of the mean when the sample size was 10, the value of t is 2.262 whereas the value of from the normal distribution is 1.96 (regardless of sample size).

- Control Chart Multiplication Factors - Factors as applied in the manual are multipliers used to calculate statistical control limits for control charts. They provide a method of approximating the distribution of all the values in the population when calculating statistical limits. This is necessary because the distribution of sample values differs from the distribution of population values. The factors used in this manual are D_3, D_4, B_3, B_4, A_1 and A_2. Definitions of these factors and formulae for computing them are in Reference 6-2, Appendix III. Tables with the factors used for the 99 percent confidence interval are in Appendix A-2. The application of each of the factors is:

  D_3 - Compute the 3 sigma lower control limit for a range control chart.

  D_4 - Compute the 3 sigma upper control limit for a range control chart.

  B_3 - Compute the 3 sigma lower control limit for standard deviation or coefficient of variation control charts.

  B_4 - Compute the 3 sigma upper control limit for standard deviation or coefficient of variation control charts.

  A_1 - Compute 3 sigma upper and lower control limits for average control charts, using $\bar{\sigma}$.

  A_2 - Compute 3 sigma upper and lower control limits for average control charts, using $\bar{R}$.

Definitions and use of control charts will be discussed in other sections.

- Replicates - Repeated but independent tests or analyses of the same sample, under the same conditions. Replicates may be performed to any degree, e.g., duplicates, triplicates, etc.

- Precision and Accuracy - The concepts of precision and accuracy must be understood in formulating control chart limits. A system, e.g., instrument, will not necessarily display identical readings even when making measurements on a single sample. Rather, the values will tend to scatter about a point of central tendency. Precision is the ability of a system to reproduce its own levels of performance, e.g., measurements. Precision is determined from replicate analyses. It represents the variability of results among the replicate analyses. Precision can be expressed in terms of standard deviation, variance, or range.

  Accuracy is the difference between a measurement and its true value. It describes the magnitude of error in a measurement. It is expressed either as a relative error, expressed in percentage, or in terms of units, e.g., parts per million. Usually, critical parameters in an analytical system should be evaluated in terms of accuracy or precision.

- Performance Levels - Defined, acceptable levels of performance. These levels must be specified before evaluating the analytical performance of a system. Some sources of information which could possibly affect the choice of performance levels are *Federal Register* specifications, EPA recommendations, method specifications, and good engineering practices.

Appendix A-2

CONTROL CHART
MULTIPLICATION FACTORS

Appendix A-2

CONTROL CHART MULTIPLICATION FACTORS*

Observation in SUB-GROUP, n	FACTORS FOR CONTROL LIMITS					
	A_1	A_2	B_3	B_4	D_3	D_4
2	3.67	1.880	0	3.267	0	3.267
3	2.39	1.023	0	2.568	0	2.575
4	1.88	0.729	0	2.266	0	2.282
5	1.60	0.577	0	2.089	0	2.115
6	1.41	0.483	0.030	1.970	0	2.004
7	1.28	0.419	0.118	1.882	0.076	1.924
8	1.17	0.373	0.185	1.815	0.136	1.864
9	1.09	0.337	0.239	1.761	0.184	1.816
10	1.03	0.308	0.284	1.716	0.223	1.777
11	0.97	0.285	0.321	1.679	0.256	1.744
12	0.93	0.266	0.354	1.646	0.284	1.716
13	0.88	0.249	0.382	1.618	0.308	1.692
14	0.85	0.235	0.406	1.594	0.329	1.671
15	0.82	0.223	0.428	1.572	0.348	1.652
16	0.79	0.212	0.448	1.552	0.364	1.636
17	0.76	0.203	0.466	1.534	0.379	1.621
18	0.74	0.194	0.482	1.518	0.392	1.608
19	0.72	0.187	0.497	1.503	0.404	1.596
20	0.70	0.180	0.510	1.490	0.414	1.586
21	0.68	0.173	0.523	1.477	0.425	1.575
22	0.66	0.167	0.534	1.466	0.434	1.566
23	1.65	0.162	0.545	1.455	0.443	1.557
24	0.63	0.157	0.555	1.445	0.452	1.548
25	0.62	0.153	0.565	1.435	0.459	1.541

*References: 6-2 Appendix III, 6-4 Appendix II Table M.

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Appendix B-1

GLOSSARY OF TERMS

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Appendix B-1

GLOSSARY OF TERMS

Acceleration - The rate of change of velocity per unit time. e.g., miles per hour per hour.

Advance (spark) - To cause the occurrence of spark earlier in the combustion cycle.

Air Cleaner (Carburetor) - A device mounted on the carburetor through which air must pass on its way into the carburetor air horn. It filters out dust particles, silences intake noise, and safeguards against backfire through the carburetor.

Air Guard - An air injection exhaust emission system used by American Motors Corporation.

Air Injection - A system where pressurized air is transmitted to each exhaust port of the engine. Here the fresh charge of air mixes with hot exhaust gases and promotes more complete burning of hydrocarbons and carbon monoxide.

Air Injection Reactor - An air injection exhaust emission system using a pump to inject air into a specially designed exhaust manifold.

Air Pump - An engine, belt driven, air pump incorporating a rotor and three vanes. The vanes rotate freely about an off-center pivot pin and follow the circular-shaped chamber. A basic component of all air injection type exhaust emission systems.

Aldehydes - Partially oxidized hydrocarbons in which oxygen atoms are bonded to carbon atoms at the end of a molecular chain. These gases contribute to the formation of eye irritating materials formed in photochemical smog.

Ambient Air - Air in the surrounding area which is used as the diluent air by the CVS system.

Ambient Temperature - The measured temperature of the air which surrounds an object.

Amplifier - A device employing vacuum tubes or transistors, which multiplies an input signal and provides an output of greater magnitude.

Analytical System - Refers to all the components of an analyzing system including the instruments, pumps, flow controllers, valves, lines, output devices etc., required to perform the exhaust analysis.

Arithmetic Mean - A value that is computed by dividing the sum of a set of terms by the number of terms; average value.

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Atom - The smallest subdivision of an element which retains the chemical characteristics of that element.

Attenuator - A device for proportioning input signals. i.e., to change the span or range of an instrument by a known increment or multiple.

Audit (general) - A methodical examination and review to determine the quality of some function or activity.

Automatic Driver - An instrument that mechanically drives a car through a test cycle by electromagnetically (or engine vacuum) comparing the speed variations recorded on magnetic tape to the dynamometer roll revolutions.

Backfire - An explosion in the induction of exhaust system.

Backfire Suppressor Valve - A device used in conjunction with the early design "Thermactor" exhaust emission system. Its primary function is to lean-out the excessively rich fuel mixture which follows closing of the throttle during deceleration. Allows additional air into the induction system whenever intake manifold vacuum increases.

Bag - An enclosure made of flexible inert material (usually teflon or tedlar) used to store diluted samples of either emission or ambient air.

Barometric Pressure - Atmospheric force per unit area exerted at a given point.

Binary Gas Mixture - A mixture of two gases only in a container (cylinder, bag, etc.). This is also referred to as a single component blend and is not a double component blend which is a mixture of three gases used as a standard for 2 different analyzers. In calibration mixtures air is usually regarded as a single gas.

Blowby - Name given to the high pressure gases that escape past the engine piston rings into the crankcase during compression and power strokes. More pronounced on high mileage engines because of imperfect seal of piston rings to cylinder wall. Comprised mostly of unburned fuel-air mixture.

Blower - See positive displacement pump.

Buoyancy - The tendency of a body to float or rise when submerged in a liquid or gas. The power of a liquid or gas to exert an upward force on a body placed in it.

Brake Horsepower - A unit measurement of work; e.g., amount of horsepower delivered to the transmission by the engine.

Calibration - Process of establishing analyzer response to a series of known concentrations of gases.

Calibration Curve - The points established in calibration are mathematically treated to determine the best fit line to form the curve.

Calibration Gases - A set of gases of known concentrations within a desired range, for the purpose of establishing calibration curves. The levels of concentration must bracket the level for which actual measurements are to be made.

California Air Resources Board - Name of the official regulating body in California which established criteria and recommends legislation for the control of and standards for vehicle emissions.

Cam - A device that controls or alters motion. For example, the ignition distributor breaker cam, in rotating, causes contact points to open and close.

Capacitor (Condenser) - An electrical device that permits the storage of energy.

Capillary Column - A section of tubing with very small inside diameter used to restrict flow; FID, NOCL.

Carbon - A nonmetallic element (C) found as a constituent of petroleum in combination with hydrogen atoms, e.g., hydrocarbons; generally measured as ppmc by FID.

Carbon Dioxide (CO_2) - A heavy, colorless nontoxic, noncombustible gas; a by-product of complete combustion.

Carbon Monoxide (CO) - A colorless, odorless, toxic, combustible gas; a by-product of incomplete combustion.

Carburetor - A device to meter and mix air and fuel in the correct proportion, according to the demands of the engine.

Catalytic Muffler - A muffler packed with chemicals which acts as a catalyst in oxidizing HC and CO; promotes completion of the combustion of HC and CO.

Centigrade - A temperature scale calibrated at 0°, to the melting point of ice, and 100°, the boiling point of water.

Centrifugal Force - The force tending to make rotating bodies move away from the center of rotation due to inertia.

Centrifugal Advance Mechanism - A device that advances ignition timing with relation to engine speed.

Centrifugal Filter Fan - A filter fan mounted on the air pump drive shaft used to clean the air entering the air pump.

Certification - Acceptance, by the Administrator EPA, of a vehicle type which has met the Federal Standards for exhaust and evaporative emission control.

Charcoal - Treated carbonaceous material obtained by the imperfect combustion of wood or other organic substances, used to filter or absorb gasoline vapors.

Chassis Dynamometer - Apparatus used for applying and measuring rolling resistance and speed of vehicles; specifically used for exhaust emissions testing by simulating inertia and horsepower encountered during the performance of steady and transient states of a vehicle on the road.

Check Valve - A one-way valve to prevent exhaust gas backflow into the air pump.

Chemiluminescent - A chemical reaction that gives off energy directly in the form of light.

Choke Plate - A valve in the carburetor which chokes off air flow through the carburetor air horn producing a partial vacuum at the main discharge nozzle(s) for greater fuel delivery, as during cranking.

Chopper - A two-segmented blade rotating at 5 revolutions per second in order to block simultaneously, ten times (10 x) per second, the infrared beams generated by tungsten filaments inside the NDIR analyzer cells.

Closed System - Related to a crankcase emission system which obtains fresh air through the carburetor air cleaner and routes it through a tube to the filler cap; there is no venting to the atmosphere.

Closed Throttle - Position of carburetor throttle plate at engine idle. See also wide open throttle.

Code Number - Identification number of any exhaust emission test conducted.

Cold Start Test - A Federal test for exhaust emissions which is performed after a 12-hour soak period.

Cold Start "Transient" - First 505 seconds of the 1975 Federal driving cycle. (C.S.T.)

Cold Start "Stabilized" - Last 867 seconds of the 1975 Federal driving cycle (C.S.S.).

Combustion - The burning process which requires three basic ingredients: fuel, oxygen, and ignition.

Computer - An electronic system capable of performing automatically a long series of computational or logical operations on stored data, using an appropriate sequence of stored instructions.

Computer Program - The complete plan for the solution of a mathematical problem; more specifically the complete sequence of machine instructions and routines necessary to solve this problem.

Concentration - The weight or volume of one substance with respect to the total mixture, e.g., grams per liter, parts per million.

Condenser (Cooling) - A water-filled container cooled by ice or refrigeration, housing 1/4" O.D. coils of stainless steel tubing. Its purpose is to cool the sample exhaust gas to the dew point which removes the moisture in the sample by condensation.

Console - The structure which houses the analyzers, amplifiers, condenser, filters, recorders, pumps, plumbing, and controls required to measure exhaust emission gas concentrations. Also referred to as an analytical system.

Constant Volume Sampler (CVS) - Sampling system in which diluent air is combined with vehicle exhaust gases and is collected in bags for analysis.

Control Chart - A chronological, graphical comparison of actual data quality characteristics with limits reflecting the ability to perform as shown by past experience with the testing variables.

Control Limits - A quality control technique employing a mean (average) and upper and lower limits.

Control System - Standard production components for the control or reduction of exhaust and evaporative emissions.

Controlled Combustion System - Modified engine exhaust emission system used by General Motors Corporation.

Correlation Program - A quality control application for establishing test cell equivalence by minimizing variability.

Correlation Vehicle - Vehicle used to obtain emission test data for the correlation program. These vehicles are specially prepared to minimize variability in HC, CO, and NO_x levels.

Crankcase Emissions - Airborne substances emitted to the atmosphere from any portion of the crankcase ventilation or lubrication system.

Crowd - An acceleration made at a continually increasing throttle opening.

Cubic Centimeter Displacement (C.C.) - The total piston displacement of an engine obtained from piston diameter, number of pistons, and piston stroke, calculated in cubic centimeters, 1 inch = 2.54 cm.

Cubic Inch Displacement (C.I.D.) - Total piston displacement calculated in cubic inches. See cubic centimeter displacement.

Curb Weight - Actual or manufacturers estimated weight of vehicle in operation with standard equipment.

Cycle - A series of events that occur in a given sequence; e.g., 1 - in an internal combustion engine, the four strokes; intake, compression, power, exhaust. e.g., 2 - in the Federal "Cold Start Test", the series of transient and steady state driving modes.

Cycling - Oscillation from a low level to a high level characterized by periodicity.

Dashpot - A device whose function is to slow down the closing action of the carburetor throttle plates; aids in the reduction of rich mixtures in the intake manifold during deceleration.

Data - Detailed information.

Deceleration - The rate of decrease of velocity per unit of time (Negative acceleration).

Deceleration Valve (Distributor Vacuum Advance Control Valve) - A device used in conjunction with the dual diaphragm vacuum advance unit to advance timing under deceleration conditions.

Deflection - Chart recorder pen position reflecting instrument response on a scale to a gas.

Density - The ratio of the mass of a substance to its volume; e.g., lb/ft3.

Desiccant - A chemical compound used for the extraction of moisture from exhaust gases entering the sampling train.

Deviation - Departure from an average value or norm.

Dew Point - The temperature at which vapor, such as water, begins to condense.

Diaphragm - A flexible membrane, made of fabric and rubber, clamped at edges and spring loaded, used in various automotive components; pumps and controls.

Dieseling - Auto ignition, usually applied after vehicle ignition is shut off.

Differential Pressure - Pressure difference obtained by measuring two separate reference points, e.g., manometer before and after CVS blower.

Diluent - A diluting agent such as the nitrogen or air used in preparation of standards gravimetric - of or relating to measurement by weight.

Diluent Air - Ambient air drawn into the CVS system to dilute the raw exhaust gases.

Dilute Exhaust Gas - The combination of vehicle exhaust gases and diluent air.

Dilution Factor - A number by which lean or rich fuel mixtures are adjusted to a stoichiometric mixture.

Distributor - The part of the ignition system which closes and opens the circuit to the ignition coil and distributes the resulting high voltage surges from the ignition coil to the proper spark plugs.

Distributor Plate (Stationary) - The plate in the distributor that is fastened to the housing and does not move.

Distributor (Sub-Plate) - The plate in the distributor that pivots on the stationary plate with movement of the vacuum advance. The points and condenser are usually fastened to this plate.

Distributor Vacuum Advance Control Valve - Refer to deceleration valve.

Diurnal Breathing Loss - Fuel evaporative emissions resulting from daily fluctuations in temperature to which the fuel system is exposed.

Drift - Deviation of instruments from zero or set point after calibration. See cycling.

Driver's Aid - An electronically controlled chart recorder with pre-traced driving schedule. The pen deflection is directly proportional to the roll revolutions and therefore by accelerating and decelerating the vehicle the driver can maintain the pen on this driving schedule. The chassis dynamometer roll revolutions are converted into electrical signals which then drive the pen on the chart recorder.

Driver Variability - Inability of a single driver to repeat a CVS cycle precisely the same way each time; also inability among drivers to drive a CVS cycle precisely the same way; variability.

Dry Bulb Temperature - The temperature indicated when a thermometric device, such as a thermometer, is inserted in an air vapor mixture (ambient air); as applied to exhaust emissions testing, the temperature, in degrees Fahrenheit, in front of the radiator cooling fan.

Dual-Diaphragm - A vacuum advance mechanism that attaches to the engine distributor to control spark timing. One diaphragm provides normal ignition timing advance for starting and acceleration; the other diaphragm retards the spark during idle and part throttle operation. Some engine/transmission applications utilize a special valve to advance timing during deceleration to further reduce emissions.

Duct - A tube or channel used in conveying air or liquid from one point to another; in emission systems, a device used in the temperature regulation of carburetor intake air in conjunction with a thermostatic valve and vacuum motor.

Duct and Valve Assembly - An assembly incorporated in the air cleaner to regulate the temperature of carburetor intake air.

Dump - Bypass of excess sample flow of exhaust gases during analysis.

Dynamometer - An apparatus for measuring mechanical power, as of an engine.

Dynamometer Driving Schedule - Pre-traced curves representing a specific series of idle, acceleration, cruise, and deceleration modes, of different rates.

End of Line Test - Abbreviated exhaust emission analyses performed on the vehicles at the end of the production line.

Emission - Substances emitted to the atmosphere by: chemical reactions between sunlight and natural organic compounds, evaporation, and combustion of fuels.

Evaporate - To change from a liquid to a gas.

Event Marker - An electric switch operated ink pen on the chart recorder used to time-orient the chart record with driving mode changes.

Exhaust Emission - Substances emitted to the atmosphere from any opening downstream from the exhaust port of a vehicle engine; by-products of hydrocarbon combustion. Included are raw hydrocarbons, carbon monoxide, carbon dioxide, oxides of nitrogen, oxygen, and particulate material.

Exhaust Gas Recirculation (EGR) - A system in which a portion of the exhaust gases are recirculated into the intake manifold for the reduction of nitric oxide by minimizing peak combustion temperatures and pressures.

Exhaust Manifold - The part of the engine that provides a series of passages through which burned gases from the engine cylinders flow.

Exhaust Volume - The amount of gases emitted from the exhaust during a CVS test; calculated theoretically by using the blower revolutions, CO_2 ratio, and test time.

Fahrenheit - A temperature scale calibrated at 32°, to the melting point of ice, and 212°, the boiling point of water.

False Start - An engine stall prior to turning on the driving aid. A situation when an engine stops immediately after starting.

Fast Idle Cam - The mechanism of the carburetor that holds the throttle valve slightly open when the engine is cold, to provide higher engine speed.

Filter - Pressed fiber pads or fine steel gauze set in a sampling stream for the removal of particles from the gas before analysis.

Flame Ionization Detector - An analytical instrument used to measure hydrocarbon concentration. The hydrocarbons are first broken up into ions by combustion in the flame. These ions then migrate toward electrodes creating electrical current which is measured. The amount of current generated is directly proportional to the concentration of hydrocarbon.

Flow Rate - Volume of gas or fluid that passes a given cross section area per unit time; e.g., cubic feet/hour.

Force - Strength exerted against a mass to cause it to change motion or deform.

Frequency - The rate of occurrence of an observed value of a variable.

Frequency Distribution - Graphical or tabular description of the frequency of range of values of the variable.

Fuel - Gasoline normally used in internal combustion engines for emissions testing; e.g., Indolene 30, Indolene Clear (HO).

Fuel Evaporative Emissions - Unburned fuel vapors collected in charcoal traps from two areas, air cleaner and vehicle canister. Part of Federal Certification Standards.

Fuel system - The combination of fuel tank, fuel pump, fuel lines, and carburetor, or fuel injection components, and includes all fuel system vents and fuel evaporative emission control systems.

Gain - Amplification of a signal.

Gain Control - Calibrated potentiometer for the adjustment of signal amplification. Used to set upscale calibration point while flowing a normalizing gas.

Gas Permeable - Any material that allows gas to diffuse through its surface. Usually referred to in O_2 analyzer membrane.

Gram - Metric unit of weight equal to approximately 0.035 ounces.

Grams per mile - Unit of measurement for accumulated weight of exhaust emissions per vehicle mile driven on the chassis dynamometer roll.

Gravity - The gravitational attraction of the earth's mass for bodies at or near its surface.

Gravimetric - Of or relating to measurement by weight.

Gross Vehicle Weight - Curb weight plus rated load. (Emission control systems not required currently on engine applications for vehicles that exceed 6000 lb GVW).

Hang-up - The resultant effect of residue from sample gases collecting on the inner surface of the gas sample train. This effect is evident when instruments fail to return to zero deflection with nitrogen gas introduced into the measuring system after a test. This term also applies to slide wire friction on the recorders.

Heat Build - The process by which the fuel in the vehicle's tank is heated at a prescribed rate during the diurnal breathing loss test.

Heat Exchanger - A device in the Constant Volume Sampler where cooled air or water, circulating through a sleeve surrounding the exhaust gas stream, absorbs heat from the gas thru maintaining an even temperature.

Hesitation - A temporary lack of response in acceleration rate.

Horsepower - Unit of work, equivalent to 550 foot-pounds per second.

Hot Idle Compensator - A thermostatically controlled carburetor valve that opens whenever inlet air temperatures are high. Additional air is allowed to discharge below the throttle plates at engine idle. This feature improves idle stability and does not allow the rich fuel mixture normally associated with increased fuel vaporization of a hot engine.

Hot Soak Loss - Fuel evaporative emissions collected during the first hour immediately following the dynamometer test.

Hot Start Test - Any exhaust emissions test performed after a prescribed engine warm-up period which follows the same sequences as a CVS test.

Humidity Factor (K) - correction factor used to adjust nitric oxide emission values to standard humidity at 75 grains of water per pound of dry air.

Hydrocarbons - Organic compounds containing carbon and hydrogen atoms in numerous combinations (H_xC_y) which occur in nature as living organisms, crude oil, natural gas, and coal. Excessive amounts in the atmosphere are considered undesirable contaminants and a major contributor to air pollution.

Idle Limiter - A device to control the amount of adjustment of idle mixture screws, and therefore, maximum idle fuel richness of the carburetor. Also aids in preventing unauthorized persons from making overly rich idle adjustments. The limiters are of two distinct types: the external plastic limiter caps installed on the head of idle mixture adjustment screws or the internal needle type located in the idle channel.

Idle Mixture Adjusting Screws - The adjusting screw that can be turned, in or out, to lean or enrich the idle mixture.

Idle Port - The opening into the throttle body of the carburetor through which the fuel in the idle circuit discharges.

Idle Vent - An opening from an enclosed chamber through which air can pass to lean out air/fuel ratio during idle conditions.

Indolene Clear - A petroleum based, lead free, fuel for vehicles used in exhaust emissions testing. (Ref. Federal Register, Vol. 39, No. 14, Title 40, Part 85.)

Indolene 30 - Emissions test fuel containing 3 gm. of lead per gallon of fuel. (Ref. Federal Register, Vol. 39, No. 14, Title 40, Part 85.)

Inertia - A property of matter by which it remains at rest or in uniform motion in the same straight line unless acted upon by some external force.

Inertia Weights - Flywheels having specified weights which are connected to the dynamometer drive roll for the purpose of simulating vehicle inertia.

Infrared Radiation - Electromagnetic radiation from two to fifteen microns wavelength produced in nature by black body sources. Nearly all chemical compounds absorb infrared radiation and can be identified by this specific absorption. Theory of non-dispersive infrared analyzer.

Inlet Depression - Pressure differential between the dilute exhaust mixture entering the CVS positive displacement pump and the atmosphere.

Intake Manifold - The part of the engine that provides a series of passages from the carburetor to the engine cylinders through which the air fuel mixture flows.

Integrate - A method that uses the collective properties of a group of numbers to compute a value which is representative of that group - average value.

Inverse - Direct opposite. When two factors are inversely related one increases as the other decreases proportionally.

Ions - An atom or group of atoms that carries a positive or negative electrical charge.

Kickdown - Release of the automatic choke from high cam position on a cold engine by increasing engine speed to 2,500 ± 100 RPM and releasing accelerator within 3 seconds. Deactivation of the fast idle mechanism.

Knock (Ping) - Auto ignition that is audible.

Lead - Tetraethyl lead added to gasoline as a lubricant and antiknock additive.

Light Duty Vehicle - A motor vehicle designed for the transportation of persons or property on a street or highway and weighing 6000 pounds gross vehicle weight or less.

Linear - A relationship between two variables such that a change in one is accompanied by a proportional change in the other.

Loaded Vehicle Weight - Vehicle curb weight of a light duty vehicle plus 300 lbs.

Magnehelic Gauge - Pressure gauge referred to by the manufacturers brand name. Commonly incorporated in NDIR consoles.

Malfunction - The act of performing improperly or a condition describing vehicle or test equipment failure.

Manifold - A tube or pipe for conveying liquids or gases as in the intake of fuel/air mixtures and the exhaust of burned gases.

Manifold Control Valve - A thermostatically operated valve in the exhaust manifold for varying heat to intake manifold during the engine warm-up period.

Manometer - A glass tube, either "u" shaped or linear, filled with a liquid and clamped against a retainer having a graduated scale used to measure pressure or vacuum.

Mass - The quantity of matter in a body as measured in its relation to inertia.

Maximum Rated Horsepower - Maximum brake horsepower output of an engine.

Micron - A unit of length equal to 3.937×10^{-5} inch used in measuring wavelengths of light, and particle diameter.

Modal Analysis - Summation of exhaust emission data for each specific mode throughout a test cycle.

Mode - Division of a test cycle into established segments which describe the vehicle's operating state; acceleration, deceleration, cruise, and idle conditions. (Transient or steady states.)

Modification - A change from the original, such as engine modifications; design change, component change, etc.

Modulator - A device used to integrate two signals into one; to vary the amplitude, frequency, or phase of a carrier wave or signal.

Mole - The molecular weight of a compound expressed in grams; the number of moles of a compound is equal to its mass in grams, divided by the molecular weight.

Mole Percent - The number of moles of a compound in a mixture divided by the total number of moles and multiplied by 100.

NBS Cylinder - A gas standard prepared and certified by the National Bureau of Standards.

Nitric Oxide - A colorless, toxic gas (NO) formed by the oxidation of nitrogen; also a by-product of the combustion of hydrocarbon fuels.

Nitrogen - A colorless, tasteless, odorless, nontoxic gas (N_2) that constitutes 78 percent of the atmosphere by volume.

Nitrogen Dioxide - A brown, highly toxic gas (NO_2) formed by the union of nitric oxide (NO) and oxygen (O_2) or ozone (O_3).

Non-Dispersive Infrared - NDIR: gas analyzer which uses a specific infrared wavelength for analyzing each different component; e.g., HC, CO, CO_2, and NO.

Non-Dispersive Ultraviolet - NDUV: gas analyzer which uses a specific ultraviolet wavelength for analysis for NO_2. This instrument is in limited use at the present time.

Normal Distribution - A frequency distribution whose graph is bell-shaped and symmetrical. This distribution is common in the data from many natural events and many measurement processes.

NO_x - Refers to the oxides of nitrogen which are produced during and after combustion. The sum of the NO and NO_2 concentrations in the exhaust sample.

NO_x Analyzer- Analytical instrument used to analyze NO and NO_2 by chemiluminescence. The formation of NO_2 by the reaction of NO and O_3 (ozone) emits light the intensity of which is directly proportional to the concentration of NO and can be measured by a photomultiplier tube.

Nozzle - A restricted orifice or hole; the final outlet for air entering the exhaust manifold on injector emission systems; fuel discharge point of the carburetor main system.

Open System - Crankcase emission control system which draws air through the oil filler opening.

Oxidation - A chemical reaction in which oxygen combines with an element or compound to form a new compound, e.g., the action of oxygen on iron to form rust; the action of oxygen on hydrocarbons to form oxidized hydrocarbons (aldehydes).

Oxides of Nitrogen - See NO_x.

Oxygen - An element that is found free as a colorless, odorless, tasteless gas constituting 20.9 percent of atmospheric air by volume; supports life and the combustion process; contributes to the formation of exhaust process; e.g., CO, CO_2, NO, H_2O.

Partial Pressure - The pressure exerted by any single gas in a mixture of gases.

Part Throttle Acceleration - An acceleration made at entirely wide open throttle (from any speed).

Photochemical Smog - Misnomer for a type of air pollution formed by the reaction of sunlight with hydrocarbons, nitrogen oxides, and ozone. Smog is a combination of smoke and fog which is not necessary for the formation of photochemical air pollution.

Photomultiplier - A vacuum tube which measures light intensity and amplifies this signal into milliamperes.

Polyurethane - Synthetic substance used in filtration materials normally associated with filtering carburetor inlet air.

Positive Crankcase Ventilation Valve - Controls crankcase vapors discharged into the engine intake system and passes them through the engine cylinders rather than being discharged into the air.

Positive Displacement Pump - A pump, usually of the rotary vane type, which displaces a certain volume per pump revolution. This volume theoretically does not vary, therefore, knowing the number of revolutions of the pump, the inlet depression and temperature and the calibrated displacement, the total volume passed through the pump can be calculated. This type of pump is the basis for the design for most constant volume samplers.

Potentiometer - A three terminal, variable resistance in the analyzer amplifier/control sections used to adjust the upscale calibration point.

Power Absorption Unit - A component of the chassis dynamometer for the absorption of vehicle power.

Power Switch - Generally an on-off switch, but as applied to NDIR a three-position rotary switch which controls the electronic circuitry; (1) the OFF position removes power from all circuit components; (2) in READ position, the meter indicates the output of the amplifier/control section and this position is used for calibration and analysis; (3) in TUNE position, the meter indicates the rms value of the half-wave rectified carrier wave.

Pressure - Force applied to or distributed over a surface; measured as force per unit area; e.g., lbs/sq.in. Absolute Pressure: Measure with respect to zero pressure. Gauge Pressure: Measure with respect to atmospheric pressure. e.g., absolute pressure = gauge pressure + atmospheric pressure.

Primary Calibration Gas - A gas having a known concentration which has been accurately measured, usually gravimetrically. The concentration should be known to within ±0.5 percent.

Probe - Stainless steel tubing which is fitted inside a test vehicle tailpipe for the collection of exhaust gases for analysis.

Procedure - A step-by-step method of conducting a test or performance of an operation.

Purge - An operation included in the sampling and analysis of concentrated exhaust gases by which a non-reactive gas such as nitrogen is flowed through the analyzer in the reverse direction for the purpose of driving out responsive gases. The process by which the sample bags are filled and evacuated with air or N_2 for the purpose of removing the sample gas.

Quality - The composite product characteristics of engineering and manufacturing that determine the degree to which the product in use will meet the expectations of the customer. For testing purposes it is the degree to which the measurement system produces emission data within acceptable limits.

Quality Assurance - A system for integrating the quality functions of the various groups in an organization so as to assure production and service at the most economical levels which satisfy the quality requirements of the testing facility or contractor.

Quality Control - Any program or device employed to minimize sources of variation inherent in all analytical and technical functions. Any procedure designated to maintain the reliability of emission test data.

Rated Speed - Speed at which manufacturers specify the maximum rated horsepower of an engine.

Ratio - The expression of the proportional mixture of two substances, usually expressed as a numerical relationship, such as 2:1, 10:1, etc., in emission systems, concern is with air-fuel mixtures.

Raw Sampling - Collection of exhaust gases for analysis at any point between the exhaust manifold and the tailpipe.

Reactor System - Similar to an air injection system, but employing a larger exhaust manifold having insulated walls for less heat transfer to maintain high exhaust temperatures for continuing oxidation of exhaust gases in the manifold.

Recorder Response Time - The time required for the chart recorder pen to move from zero to 90-100 percent of upscale position on the introduction of a normalizing gas to the analyzer.

Relief Valve - A pressure limiting valve located in the exhaust chamber of the air supply pump. Its function is to limit the air flow to the exhaust ports when the vehicle exhaust back-pressure exceeds a predetermined value.

Retard - To delay the timing of the spark to the combustion chamber; usually associated with spark timing mechanisms of the engine.

Road Draft Tube - A means by which the engine crankcase was ventilated prior to the introduction of crankcase emission control systems.

Road Load - The horsepower required to drive a vehicle at zero grade and zero wind velocity at a constant speed to overcome rolling and wind resistance. The value of HP varies with speed and vehicle weight.

Rolls - A common name for chassis dynamometer.

Rotometer - A gauge that consists of a graduated glass tube containing a free float for measuring the flow of a fluid or gas; a flowmeter.

Running Loss - Fuel evaporative emissions resulting from an average trip in an urban area or the simulation of such a trip.

Sampling System - The total plumbing required to obtain a representative sample of exhaust gases for analysis.

Span - The act of introducing an end point or set adjusting point gas into an analyzer and the response to a predetermined set point for that gas.

Stall - Inability of an engine to continue operating at any time other than starting (see false start).

Standard Deviation - A statistic indicating the variability of a distribution, calculated by obtaining the sum of the squares of the differences of all values from the arithmetic mean.

Statistics - A branch of mathematics dealing with the collection, analysis, interpretation, and presentation of numerical data.

Steady State - A condition of vehicle performance on the dynamometer rolls in which engine speed and/or rpm remains constant during a specific test condition; e.g., "Road Load", "Idle Emissions", "HP Setting", and "Cruise Modes".

Stoichiometric - As applied to the spark ignition engine, the ideal air/fuel mixture for complete combustion of fuel.

Stoichiometry - Applications of the laws of definite proportions and of the conservation of matter and energy to chemical activity.

Stretchiness - A lack of anticipated response to throttle movement.

Surging - A condition of leanness resulting in short fluctuations in engine and vehicular speed.

System Response Time - The time interval between the introduction of sample gas into the probe and when the chart recorder indicates the presence of this gas.

Tachometer - An instrument for measuring engine rpm.

Tank Fuel - Fuels representative of commercial fuels which are generally available through retail outlets.

Tank Fuel Volume - Volume of fuel in the fuel tank, prescribed to be a percentage of the nominal tank capacity rounded to the nearest whole U.S. gallon.

Test (emissions) - Qualitative and quantitative determinations of the various components of exhaust gases.

Test Cell - An area specifically designed and equipped for the purpose of qualitative and quantitative determinations of species of exhaust gases.

Thermostat - A valve which depends on heat to control temperature by opening or closing a damper. In emission systems, to control hot or cold carburetor inlet air.

Timing - The point at which a spark plug fires in relationship to the rotation of the crankshaft and piston.

Tip-In - Vehicle response to the initial opening of the throttle.

Top Dead Center (TDC) - The highest point a piston travels in the cylinder.

Transducer - A device which is actuated by power from one system so that it may supply power in any other form to a second system; e.g., the conversion of torque to an electrical signal for recording.

Train - See console, analytical system.

Trap - A cylindrical, usually stainless steel, device located at the bottom outlet of the condensing coils inside the ice water bath for the purpose of collecting moisture from a sample gas prior to analysis.

Tune Adjustment - NDIR: control used to tune the oscillator if meter does not indicate the correct value when the power switch is in tune position.

Uncontrolled System - A term applied to vehicles without emission control systems.

Vacuum - A term to describe a pressure that is less than atmospheric pressure.

Vacuum Advance - A mechanism which advances ignition timing in relationship to engine load conditions. This is achieved by using engine vacuum.

Vacuum Control Temperature Sensing Valve - A valve that controls manifold vacuum to the distributor advance mechanism under hot idle conditions.

Vane - Any flat, extended surface attached to an axis and moved by or in air or liquids. Part of the integral revolving portion of an air supply pump.

Vehicle Curb Weight - The manufacturer's estimated weight of the vehicle in operational status including standard and optional equipment and weight of fuel at nominal tank capacity.

Ventilation - The process by which fresh air is caused to circulate, so as to replace impure air. Principle utilized in crankcase emission systems.

Visual Integration Analysis - A method for visually averaging by means of a template, raw modal deflections from test chart traces.

Wavelength - The distance between adjacent crests of the wave form in a beam of radiation.

Weighting - A numerical coefficient assigned to a term to express its relative importance in a frequency distribution; spec., in exhaust emissions testing, the modal weighting factors are based on modal time and modal exhaust volume.

Wet Bulb Temperature - The temperature, in degrees Fahrenheit, from the passage of ambient air over a wetted surface to reach a condition of dynamic equilibrium. In this state, the heat transferred from the ambient air will be equal to that transferred from the surface in the diffusing vapor; used with the dry bulb temperature to calculate relative humidity and corresponding correction factors for humidity.

Wide Open Throttle - Position of the carburetor throttle plate when the accelerator is depressed to the maximum allowable travel.

Zero Adjust - Control used to set zero point while flowing nitrogen through analyzers.

Appendix B-2

LIST OF ABBREVIATIONS

Appendix B-2

LIST OF ABBREVIATIONS

The following abbreviations are representative of terms commonly used in emissions testing. Variations in capitalization are widespread, as no specific rule governs their use. Therefore, the interchangeable use of capital or lower case letters is acceptable.

A/C	Air Conditioning
AC	Alternating Current
A.I.R.	Air Injection Reaction
AMA	Automobile Manufacturers Association
Accel.	Acceleration
Ar.	Argon
ASTM	American Society for Testing and Materials
ATDC	After Top Dead Center
BAR	Bureau of Automotive Repair (California)
Bar	Barometric Pressure
B/F	Backfire
BHP	Brake Horsepower
BTDC	Before Top Dead Center
C	Centigrade; also Carbon
CAP	Clean Air Package
CARB	California Air Resources Board; also Carburetor
CC	Cubic Centimeter(s)
C.C.S.	Controlled Combustion System
CFH	Cubic Feet Per Hour
CFM	Cubic Feet Per Minute
CGA	Compressed gas association (usually refers to a type of cylinder pressure regulator connector)
CID	Cubic Inch Displacement
CL	Chemiluminscent Analyzer
CO	Carbon Monoxide
CO_2	Carbon Dioxide
Conc.	Concentration
CSD	Certification and Surveilliance Division
CT	Closed Throttle
Cu.In.	Cubic Inch(es)
CVS	Constant Volume Sampler
DC	Direct Current
Decel.	Deceleration

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Displ.	Displacement
Dist.	Distributor

E & D	Evaluation & Development
EGR	Exhaust Gas Recirculation
EP	End Point
EPA	Environmental Protection Agency
E/S	Engine Stumble
E.S.	Engine Surge
Evap.	Evaporative

F.	Fahrenheit
FET	Federal Emission Test
FID	Flame Ionization Detector
FL	Full Load
FT.	Foot/Feet
FTP	Federal Test Procedure

Gal.	Gallon(s)
Gm.	Gram(s)
GVW	Gross Vehicle Weight

H_2	Hydrogen
HC	Hydrocarbon(s)
HDT	Heavy Duty Testing
He	Helium
HEW	Department of Health, Education, and Welfare
Hg	Mercury
HP	Horsepower
HWFET	Highway Fuel Economy Test

I	Current (electrical)
IBP	Initial Boiling Point
ICE	Internal Combustion Engine
IN.	Inch(es)
Ind.-Cl	Indolene Clear; also Indolene-HO
Ind.-30	Indolene 30
ID	Internal Diameter

K	Correction factor for Humidity

LA-4	Federal Driving Cycle
LDT	Light Duty Testing
Lb.	Pound(s)

Max.	Maximum
Mi.	Mile

Min.	Minimum; also minute(s)
Ml.	Milliliter(s)
MPH	Miles Per Hour
mm.	Millimeter(s)
mv.	Millivolt(s)
N_2	Nitrogen
NDIR	Non-Dispersive Infrared
NDUV	Non-Dispersive Ultraviolet
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOCL	Nitric Oxide Chemiluminescent
NO_x	Oxides of Nitrogen
N/V	Ratio of wheelturns to drive shaft turns
OD	Outer Diameter
OEM	Original Equipment Manufacturer
O_2	Oxygen
O_3	Ozone
Pb	Lead
PCV	Positive Crankcase Ventilation
Pot.	Potentiometer
ppm.	Parts per million by volume
ppmC	Parts per million carbon-methane by volume
Psia.	Pounds per square inch absolute
PSI(psig.)	Pounds per square inch gauge
PT	Part Throttle
PTA	Part Throttle Acceleration
PTD	Part Throttle Deceleration
QA	Quality Assurance
QC	Quality Control
R	Rankine; also resistance; also range
Rev.	Revolution
RPM	Revolution per minute
R/S	Roll Slippage
RVP	Reid Vapor Pressure
SAE	Society of Automotive Engineers
S/B	Sensitive Brakes
Sec.	Second(s)
SO_2	Sulphur Dioxide
SO_3	Sulphur Trioxide (sulphate)
S.S.	Stainless Steel

TDC	Top Dead Center
TLV	Threshold Limit Value
TML	Tetramethyl Lead
V	Venturi(s)
Vac.	Vacuum
VIA	Visual Integration Analysis
Vs	Versus
VWA	Volume Weighted Ambient
WOT	Wide Open Throttle
Wt.	Weight

Appendix C

QUALITY MANAGEMENT PROCEDURES
FOR
MOBILE SOURCE TESTING
(HEAVY DUTY DIESEL)

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INTRODUCTION

QUALITY MANAGEMENT PROCEDURES MANUAL

The Environmental Protection Agency places prime importance on the integrity and validity of data and reports generated during Mobile Source Emission Testing. To achieve an optimum degree of confidence in the ultimate results of these tests, a quality assurance program must be integrated into the emission measurement system. Primary goals of a quality assurance program are improvements in the credibility and documentation of emission measurements. The achievement of these goals calls for quality assurance in nearly all segments of emission testing activities, procurement control, standards and calibration, laboratory operations and documentation control.

This manual presents Quality Management Procedures (QMP) governing the interrelationships between quality functions and various departments. It is a means for assigning quality responsibilities to all key personnel/functions in the organization.

The chart which appears in Section 2.0 is designed to show only those functions requiring inclusion in a quality program. It does not represent any existing organizational chart either at the EPA emission facility or other organization. The line of authority and assignment of quality functions will vary with the size and scope of a particular organization.

This manual may seem too complex and extensive to be incorporated into a small company involved in Mobile Source Emission Testing, however, it can provide guidelines for the development of a Quality Assurance Program manual. In small testing facilities many of the functions and responsibilities may be delegated to a single person within the organization. The main objective of this manual, which is the assignment of responsibilities and documentation of procedures used to accomplish a quality function, should be kept in mind when planning a quality assurance program. Such a program need not be elaborate and costly to adequately assure the validity of the data produced.

The cost effectiveness and capability of a quality program is of prime importance in selling the program to top management. Therefore, in the initial planning of an emission testing quality program the ratio

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of valid to invalid tests should be considered. An extensive audit of past data and testing history would be a logical starting point in planning to reduce the number of invalid tests, decrease the overall costs of testing, and improve the credibility of test data.

The complete support of management is a prerequisite to an effective quality program. Management attitude towards the quality program will be reflected throughout the organization. Their failure to support a quality function for the sake of getting a job done faster or for an apparent reduction in cost against the advice of Quality Assurance Management will make the program ineffective from that point on. On the other hand, Quality Management has the responsibility to actually demonstrate cost effectiveness and production of valid and reliable data. Along with the careful planning, auditing and detailing of the program an analysis of its effectiveness as well as that of the measurement system must be performed.

Therefore a QMP manual is necessary to formalize and document the quality program for ease of implementation and definition. Constant review and analysis of the documented program will result in changes to procedures and assignment of responsibilities, requiring manual revisions to maintain a viable and effective program.

Other manuals documenting specific step by step procedures for the performance of emission tests, maintenance, training, etc., should be developed and utilized in the measurement system. A test procedure manual detailing the 1975 heavy duty diesel engine emission measurement procedures has been developed and is presented in Volume II of this report.

QUALITY MANAGEMENT PROCEDURES

Change and Revision Summary

EPCN Number	Date	Procedure		Procedure Title	Entered By
		Number	Revision Date		

QUALITY MANAGEMENT PROCEDURES

SECTION 1.0

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QUALILTY MANAGEMENT PROCEDURES

SECTION 2.0

ORGANIZATION

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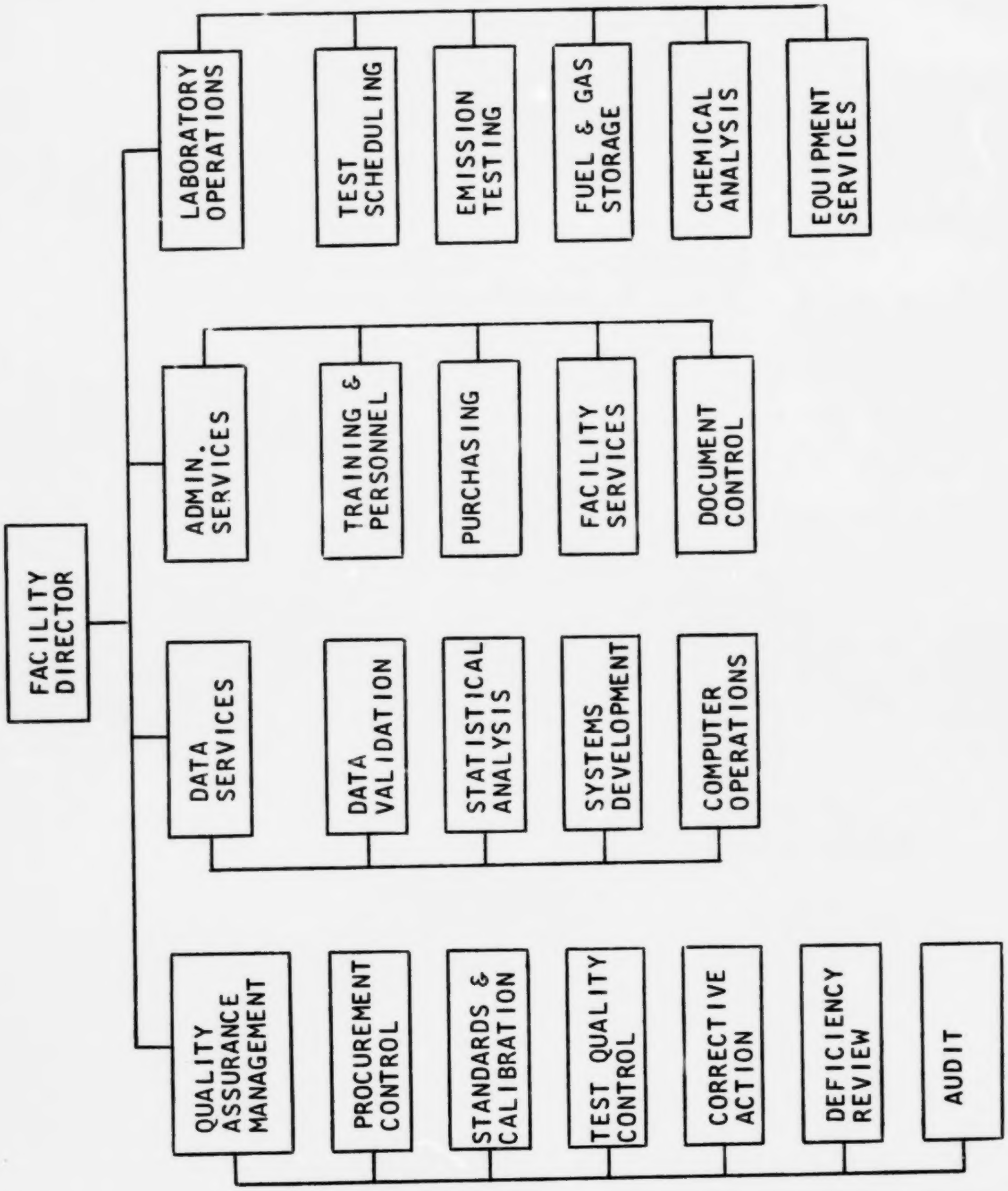
SUBJECT: FUNCTION/RESPONSIBILITY CHART


FACILITY DIRECTOR
LABORATORY OPERATIONS
TEST SCHEDULING
EMISSION TESTING
FUEL & GAS STORAGE
CHEMICAL ANALYSIS
EQUIPMENT SERVICES
ADMIN. SERVICES
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COMPUTER OPERATIONS
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STANDARDS & CALIBRATION
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CORRECTIVE ACTION
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AUDIT

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EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 2.2	REVISION DATE

SUBJECT:
FUNCTIONAL OUTLINE - ADMINISTRATIVE SERVICES

SUMMARY

The Administrative Services performs all the necessary peripheral functions required by the laboratory such as purchasing, facility engineering, equipment management, training, forms and document control.

RESPONSIBILITY		FUNCTION
Purchasing	1.	Purchases all materials, equipment, instruments, expendable items, office equipment, etc., which are used by the laboratory.
	2.	Requests Quality Assurance to provide quality requirements and approvals of purchase orders and related specifications and drawings.
	3.	Requests Quality Assurance approval and review of suppliers' products as required.
Facility Services	4.	Establishes contracts for facility services such as equipment maintenance and calibration.
	5.	Provides for all facility engineering requirements such as building modifications, plumbing, electrical wiring, heating, cooling, ventilation and general storage.
	6.	Initiates, recommends, implements safety program procedures and equipment to meet personnel and building requirements in accordance with the applicable regulations.
	7.	Controls and maintains inventory of all parts, supplies, equipment, etc., used by the laboratory. Maintains records of equipment on loan and surplus equipment inventory.
Training & Personnel	8.	Maintains personnel records and provides for personnel requirements of the laboratory by issuing, advertising and posting job descriptions of available openings. Conducts preliminary interviews and schedules interviews with the appropriate department supervisors or manager.

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RESPONSIBILITY		FUNCTION
Training & Personnel (continued)		
	9.	Conducts training and orientation programs for new employees. Provides facilities and support for technician training and evaluation programs.
Document Control	10.	Issues and controls procedures and equipment design documentation and revisions and provides for the timely revisions of procedures manuals used in the laboratory.

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 2.3-HD	REVISION DATE

SUBJECT:
FUNCTIONAL OUTLINE - LABORATORY OPERATIONS - HEAVY DUTY ENGINE TESTING

SUMMARY

Laboratory Operations is responsible for the daily operations of the test facility. It has the responsibility for the performance, calibration, maintenance and analytical requirements necessary to perform the emission tests and is responsible for the personnel, equipment and heavy duty engines used in the performance of these tests.

RESPONSIBILITY		FUNCTION
Receiving Inspection	1.	Receives and inspects engines for testing.
Test Scheduling	2.	Prepares and supervises installation of engine in the test cell and schedules emission testing.
Emission Testing	3.	Returns each engine in its original condition to the owner after successful completion of the emission test.
	4.	Conducts emission testing on vehicles according to the government regulations and procedures outlined in the Test Procedures Manual for Heavy-Duty Engine Emission Measurements.
	5.	Measures and reports Heavy-Duty Engine gaseous emissions, including smoke emission on diesel engines, according to the Federal Procedures.
	6.	Performs non-routine emission tests as requested by other divisions. Test procedures for non-routine tests shall be documented and approved by Quality Assurance and the Laboratory.
	7.	Completes all required forms and records necessary for the performance of an emission test.
Fuel & Gas Storage	8.	Provides for the proper storage and handling of Heavy-Duty Engine fuel and high pressure gas cylinders by initiating detailed procedures containing Quality Assurance checks to prevent errors such as the use of improper fuel in the engines.
Chemical Analysis	9.	Performs chemical analysis as required for receiving inspection and non-routine emission testing.

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RESPONSIBILITY	FUNCTION
Chemical Analysis (Continued)	10. Performs analysis and reports results of all calibration gases used by the facility and other facilities requesting this service. Analysis is traceable to gravimetric standards by not more than one generation.
	11. Prepares gravimetric binary gas mixtures to be used as laboratory primary standards and maintains the standards inventory to assure adequate availability of such standards.
Equipment Services	12. Designs, fabricates, inspects parts, equipment and instrument systems requested by a Job Order accompanied by appropriate approved drawings issued by Production Control. Reports completion of Job Order to Production Control.
	13. Maintains records of surplus and loaned equipment and determines disposition.
	14. Provides for periodic calibration of all instruments and equipment used in the test facility to assure the accuracy and reliability of the test data. Reports data and records of calibration to Quality Assurance.
	15. Performs maintenance of all instruments and equipment on an "as needed" or periodic basis. Performs preventive maintenance on equipment to assure trouble-free operation and avoid major equipment malfunctions.

EPA QUALITY MANAGEMENT PROCEDURE

QMP NO.	REVISION DATE
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SUBJECT: FUNCTIONAL OUTLINE - QUALITY ASSURANCE MANAGEMENT

SUMMARY

Quality Assurance has the overall responsibility for ensuring adherence to quality and reliability standards throughout all phases of mobile source emission testing and related facility operations.

RESPONSIBILITY		FUNCTION
Quality Assurance Management	1.	Formulates, recommends, and implements Quality Management Procedures, Quality Planning and Quality Cost programs consistent with management objectives and mobile source emission measurement requirements.
Procurement Control	2.	Performs source inspection of suppliers as required for quality control of procured material and services.
	3.	Monitors, plans and performs required inspection and test of all incoming materials and equipment to be used in the mobile source emission test operations. Rejects those items not meeting specifications and maintains records denoting acceptance or rejection of incoming materials and equipment.
Standards and Calibration	4.	Directs and coordinates the system for controlling the accuracy of measurement through the calibration/maintenance and control of all standards and measurement test equipment.
Test Quality Control	5.	Monitors all mobile source emission operations and verifies the authenticity of the resultant data and reports. Develops and maintains inspection plans and implements quality control programs.
Corrective Action	6.	Establishes and coordinates a systematic and timely "closed loop" mechanism for feedback of the unsatisfactory conditions to those responsible for corrective action, with follow-up until completion of satisfactory corrective action.
Deficiency Review	7.	Conducts reviews of unsatisfactory conditions to determine the cause and makes recommendations for correcting the situation.

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RESPONSIBILITY	FUNCTION
Audit	8. Conducts independent random checks of data, personnel, equipment and test cell log books to assure that proper procedures are being followed, calibration and maintenance intervals are being observed, and to judge for effectiveness of training programs.
	9. Conducts intralaboratory and interlaboratory correlation of emission measurement equipment to improve the accuracy and reliability of the test data.

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 2.5	REVISION DATE

SUBJECT: FUNCTIONAL OUTLINE - DATA SERVICES

SUMMARY

Data Services is responsible for the development of computer programs for data reduction. Processes, monitors and validates test related data to ensure the accuracy and reliability of the emission measurements. Maintains data files of test results and provides statistical programs to assist Quality Assurance in the monitoring of test data accuracy.

RESPONSIBILITY	FUNCTION
Data Validation	1. Performs data validation according to formalized procedures and informs Test Operations and Quality Assurance of invalid tests. Notifies Production Control to reschedule vehicle. Initiates corrective action and failure reports when necessary to reduce the number of invalid tests.
	2. Maintains all test data in a data file.
	3. Assists Quality Assurance in monitoring all data to verify the accuracy and reliability of emission measurements.
Statistical Analysis	4. Provides statistical analysis for Quality Assurance requirements such as determination of acceptable test parameter limits, preparation of control charts, reduction of correlation data and cost analysis.
Systems Development	5. Assists Quality Assurance and Laboratory Operations in providing for computer programs with mathematically correct formulas for the reduction of data for non-routine test programs, revision of emission data programs, and other computer programming requirements.
	6. Assists Quality Assurance in developing and implementing correlation and audit programs to assure the reliability of the data on a "cell to cell" basis and/or other laboratories performing mobile source emission testing.

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RESPONSIBILITY	FUNCTION
Computer Operations	7. Assists in the development of computer programs, processes computer programs for the reduction of test data to provide emission results on a gram per mile basis for carbon monoxide, hydrocarbons, carbon dioxide and nitric oxide. Provides results for fuel economy on a mile per gallon basis.
	8. Processes computer programs for calibration data, maintains calibration data file, and computes instrument calibration curves. Informs Quality Assurance and Test Operations when calibration and maintenance has not been performed according to prescribed intervals.
	9. Maintains the calibration gas cylinder inventory by number, type of standard and receiving analysis concentration. Maintains and processes all data related to the primary gas standards such as the NBS-SRM gases and/or those analyzed by the EPA.

QUALITY MANAGEMENT PROCEDURES

SECTION 3.0

ADMINISTRATION

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EPA QUALITY MANAGEMENT PROCEDURE	QMP NO. 3.1	REVISION DATE

SUBJECT:

PREPARATION OF QUALITY MANAGEMENT PROCEDURES

I PURPOSE

This procedure defines the formal documentation of Quality Management Procedures (QMP).

II BACKGROUND

A. The Quality Management Procedures are written to reflect the Organization's policy concerning the administrative/functional aspects of a Quality Assurance Program and the interrelationship of these functions/responsibilities.

B. The Quality Management Procedures provide the instructions required to implement a Quality Assurance Program. They define the purpose, background and scope of application of the procedure and, in addition, show the assignment of functional responsibility for performing the procedure.

III SCOPE OF APPLICATION

A. QMPs are generated by Quality Assurance in order to document the procedures and the assignment of responsibilities of all quality related functions within the mobile source emission measurement system.

B. The Quality Management Procedures are prepared by Quality Assurance and distributed by Document Control. Basically these procedures are divided into:

1. a. Changes and Revisions - QMP Form No. 7.6 on which all distributed revisions to the manual are recorded and inserted in the manual by the manager/supervisor.

   b. Introduction - contains a description of the purpose and objectives of the manual and the general philosophy of its preparation along with the organizational policy for its use.

2. Section One - Index - Lists Table of Contents.

3. Section Two - Organization - contains the function/responsibility chart and the function outlines. This chart is designed to show the required functions and responsibilities of a Quality Assurance Program but not necessarily their interrelationship which can only be done for a specific organizational structure. The functions of each major department are outlined using the "play script" format.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 5
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III SCOPE OF APPLICATION (Continued)

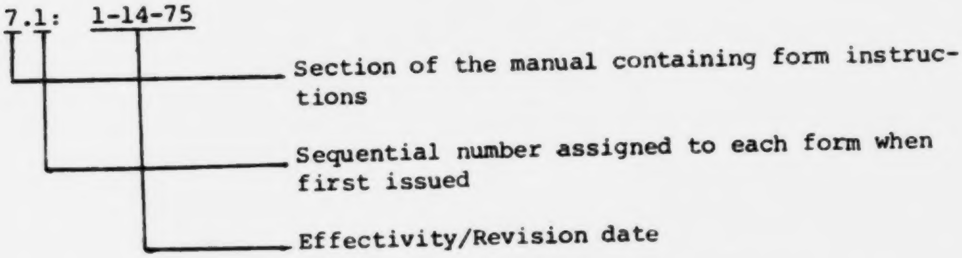
4. Section Three - Administration - contains procedures generally related to the quality functions and responsibilities of administrative services.

5. Section Four - Procurement Control - contains procedures directly related to the quality function and responsibilities of purchasing and receiving of equipment and materials used in the laboratory.

6. Section Five - Standards and Calibrations - describes quality procedures and functions applicable to equipment service and metrology.

7. Section Six - Laboratory Operations - details the quality procedures and responsibilities related to the operation of the mobile source emission testing laboratory.

8. Section Seven - Forms Instruction - describes the procedure for completion of forms required by the QMPs. Forms will be numbered as follows:



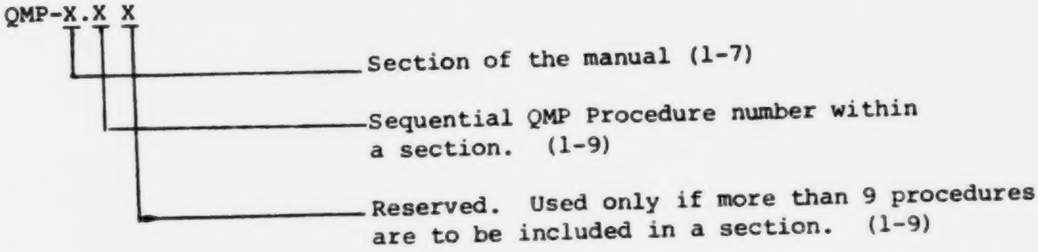
7.1: 1-14-75

Section of the manual containing form instructions

Sequential number assigned to each form when first issued

Effectivity/Revision date

C. The decimal system is used for numbering each procedure in the manual according to the section in which it appears as follows:



QMP-X.X X

Section of the manual (1-7)

Sequential QMP Procedure number within a section. (1-9)

Reserved. Used only if more than 9 procedures are to be included in a section. (1-9)

III SCOPE OF APPLICATION (Continued)

D. The format to be followed for each procedure is described as follows:

1. Section Two - contains the function/responsibility chart and the functional outlines. Functional outlines are prepared in "play script" format, i.e., the group or department responsibility for the outlined function is indicated in the left margin.

2. Sections Three through Seven - Quality Management Procedures (QMP) - follow the format:

    I PURPOSE - briefly describes the purpose or objective of the Procedure.

    II BACKGROUND - generally describes the reason or need for the procedure in addition to any pertinent historical information.

    III SCOPE OF APPLICATION - defines the areas of the measurement systems affected or involved in the particular procedure and specific effectivity such as a particular emission program or period of time are included.

    IV RESPONSIBILITIES AND PROCEDURES - describes the duties in detail for every function involved in the procedure, by order of importance and sequentially, if possible. See sample below for numbering system.

        IV RESPONSIBILITIES AND PROCEDURES

            A. Quality Assurance

                1.
                2.
                3.
                    a.
                    b.
                    c.

    In addition to the described duties, this section will usually contain a flow schematic showing the interrelationship of functions and responsibilities and/or the documentation distribution.

IV RESPONSIBILITIES AND PROCEDURES

A. Quality Assurance

1. Prepares detailed procedures in rough draft, assigns numbers to new procedures and/or revisions and designates distribution list prior to routing to Document Control.
2. Coordinates any variance between draft QMP and actual practices reported by a manager and/or supervisor and sends revised draft QMP to Document Control for final draft preparation and distribution.
3. Maintains a master file of active and historical procedures and associated documents issued.

B. Document Control

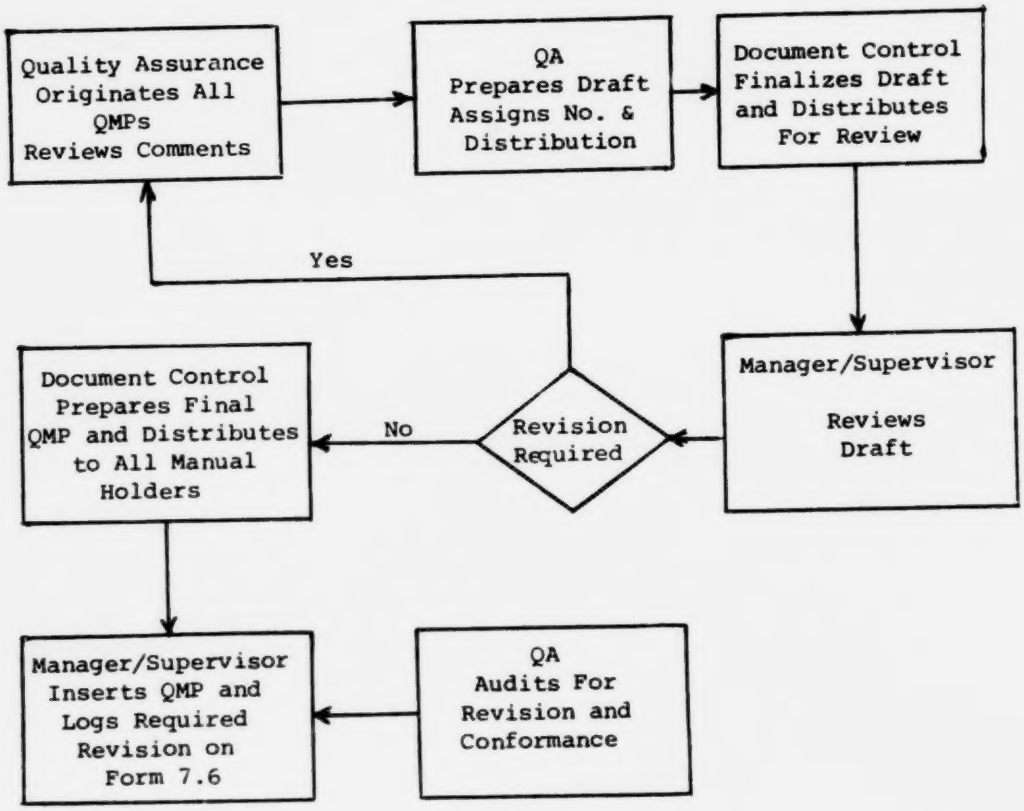
1. Distributes draft copies of procedures to management and supervisors for review and comment.
2. Distributes approved copies of procedures and/or manuals to management and supervisors requiring copies for frequent use in performance of their normal duties.
3. Maintains records of location of each manual or procedures and the person responsible for their update.

C. Department Manager/Supervisor

1. Reviews and comments on draft copies of procedures.
2. Maintains a manual in his area and becomes familiar with the contents of all procedures with responsibilities related to his particular function.
3. Records all new or revised QMPs inserted in manuals on QMP Form No. 7.6 which appears as the first page of the manual.
4. Observes and utilizes applicable procedures and responsibilities assigned to his function by the Quality Management Procedure (QMPs).
5. Initiates an Equipment and Procedures Change Notice (QMP Form No. 7.5) to inform Quality Assurance of any variances between QMPs and any applicable engineering documents and/or any observed errors in contents.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

E. Flow Schematic - QMP


Quality Assurance Originates All QMPs Reviews Comments
QA Prepares Draft Assigns No. & Distribution
Document Control Finalizes Draft and Distributes For Review
Yes
Manager/Supervisor
Reviews Draft
Revision Required
No
Document Control Prepares Final QMP and Distributes to All Manual Holders
Manager/Supervisor Inserts QMP and Logs Required Revision on Form 7.6
QA Audits For Revision and Conformance

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 3.2	REVISION DATE

SUBJECT:
DOCUMENT CONTROL

I PURPOSE

This procedure provides a method for issuing, revising, and controlling the documentation of manuals, forms and other records used in a mobile source emission measurement system.

II BACKGROUND

A. The responsibilities and procedure for preparing, numbering, implementing, and revising of forms and procedures used in the measurement systems must be clearly defined since timely response to the changing requirements of the system is of utmost importance. The maintenance of forms and manuals in a current status requires prompt submission and processing of change notices and resulting revisions, and effective control of publication and distribution of documentation to prevent obsolescence.

B. A master file of all procedures, forms, and subsequent revisions showing effective dates should be maintained for future reference.

III SCOPE OF APPLICATION

A. Manual Control - Any manual produced by a department or function within the test facility shall be submitted to Document Control, in draft form, for identification, completion, filing and distribution. Manuals specifically covered by this procedure are:

1. Quality Management Procedures
2. Training
3. Test Procedures
4. Maintenance
5. Administrative or Management Policies

All subsequent authorized revisions of the contents of these manuals shall be submitted to Document Control for distribution to the manual holders.

B. Equipment and Procedure Change Notices (EPCN) - All EPCN's shall be submitted to Document Control for assignment of a file number and distribution.

C. Forms, blueprints, equipment specifications and schematics used in the measurement system shall be submitted to Document Control for assignment of a document identification number and when necessary preparation and distribution of a form instruction.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 3
APPROVED BY:		DATE ISSUED:

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IV RESPONSIBILITIES AND PROCEDURES

A. Quality Assurance

1. Originates and revises the contents of the Quality Management Procedures Manual as required.

2. Audits manuals, EPCN's and forms being used by the Laboratory on a regular schedule for proper identification and format, current revisions, and adequate maintenance of document files.

3. Reports results of audits to Manager/Supervisor, coordinates and monitors corrective action when necessary.

4. Approves all new or proposed revisions of forms prior to publication.

5. Approves format and distribution list of all laboratory notebooks/log books.

B. Document Control

1. Coordinates and distributes "Review and Comment" draft copies, obtains approval and release of final draft documents.

2. Issues, subject to department management approval, manuals, copies of procedures and forms to employees requiring copies for frequent use in performance of their normal duties.

3. Maintains control of procedure manual masters and manual distribution list.

4. Assigns form reference numbers to all forms.

5. Maintains master file of all forms.

6. Distributes approved copies of records forms to management, other agencies and testing laboratories requiring copies for use in performance of their normal duties.

7. Distributes laboratory notebooks/logbooks by sequential number for use in the laboratory, and provides instructions on the format to be followed in making entries. Maintains a file recording the name of the person(s) responsible for the notebook/logbook, location and other applicable information.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

C. Manual Holders

1. Submit requests for forms, manuals, EPCN's and log books to Document Control. Submit proposed procedures, forms, etc., in draft form to Quality Assurance and Document Control with appropriate "Review and Comment" distribution list.

2. Maintain manual in current status in accordance with distributed change notice.

3. Submit any change request on an EPCN (QMP Form 7.5) to Laboratory Operations.

4. Returns manual to Document Control when no longer required, or when terminating employment.

EPA QUALITY MANAGEMENT PROCEDURE

QMP NO.	REVISION DATE
3.3	

SUBJECT: FORMAL TRAINING PROGRAMS

I PURPOSE

This QMP establishes guidelines for preparation and presentation of formal Quality Assurance training programs.

II BACKGROUND

Quality Assurance will provide formal training on relevant Quality Assurance topics to personnel from Quality Assurance and interfacing organizations such as Engineering and Test Laboratories personnel. Training programs will be scheduled and certifications issued upon completion.

III SCOPE OF APPLICATION

Quality Assurance training programs should reinforce the recognition of the importance of quality in each individual's efforts in addition to specific job or subject matter training. The programs should be directed not only to Quality Assurance personnel, but also to personnel in interfacing organizations.

IV RESPONSIBILITIES AND PROCEDURES

A. Quality Assurance Manager/Supervisor

1. Selects a subject of interest for a training program, to consist of a training session or series of sessions. Examples of such subjects are statistical quality control, configuration control, sampling plans, special process requirements, Federal Register requirements, etc. Discusses subject matter and training requirements with training coordinator.
2. Maintains records of certificate holders when periodic recertification is required.
3. Notifies affected supervisor prior to expiration dates for certificate holders under his supervision, and arranges with test-coordinator to conduct examinations to verify continued proficiency of individuals requiring recertification.

B. Training Coordinator

1. Determines total time required for training session and personnel to attend.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 2
APPROVED BY:		DATE ISSUED:

IV RESPONSIBILITIES AND PROCEDURES (Continued)

B. Training Coordinator (Continued)

2. Assigns personnel to prepare lesson plan and give presentations.

3. Obtain concurrence from management of other organizations for attendance of their personnel.

4. Establishes date, time and location schedule.

5. Notifies attendees and supervision of the topic and training program schedule 2 weeks in advance.

6. Follows up with scheduled attendees a week prior to training session to verify their availability for time established. Notifies supervisor in case of conflict.

7. Issues a certificate to attendees on successful completion of program.

8. Arranges recertification training and examination as required.

C. Personnel Assigned to Give Presentation

1. Prepares lesson plan and presentation to cover the subject in the time allotted.

2. Prepares a summary of the training session to be issued to attendees as an outline.

3. Reviews lesson plan presentation and summary with Quality Assurance Manager/Supervisor.

4. Presents training material to the attendees at the scheduled sessions.

QUALITY MANAGEMENT PROCEDURES

SECTION 4.0

PROCUREMENT CONTROL

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EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 4.1	REVISION DATE

SUBJECT:

PROCUREMENT DOCUMENT REVIEW

I PURPOSE

This procedure establishes the requirements for review of procurement documentation to ensure the inclusion of quality and reliability provisions.

II BACKGROUND

Procurement documents are used for the purchase of materials, supplies and services used in implementing mobile source emission testing. To maintain a high level of quality throughout the program it is essential that these documents be reviewed for the inclusion of necessary quality and reliability requirements.

III SCOPE OF APPLICATION

A. All procurement documents for material, equipment or services will be subject to review and approval by Quality Assurance prior to release and placement.

B. Certain items, procured on a routine basis and as determined by mutual agreement between procurement and QA, may be purchased without QA review and approval.

C. Programs will be reviewed to determine the scope of the quality and reliability requirements applicable to the contracts and the associated procurement activities.

IV RESPONSIBILITIES AND PROCEDURES

A. Purchasing

1. Routes all procurement documents for the purchase of material, supplies and services used in implementing emission testing to Quality Assurance for review and application of quality and reliability provisions.

B. Quality Assurance

1. Reviews each procurement document to determine applicable quality requirements and coordinates with other divisions/departments as necessary to assure consideration of all quality and reliability interests.

2. Applies quality and reliability requirements to procurement documents.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 2
APPROVED BY:		DATE ISSUED:

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IV RESPONSIBILITIES AND PROCEDURES (Continued)

B. Quality Assurance (Continued)

3. Enters evidence of Quality Assurance approval on procurement documents and returns them to purchasing.

4. Maintains records of procurement document review activities.

C. Procurement Requirements

The following quality requirements are generally applicable to all procurement actions.

1. Approved Suppliers - Quality Assurance approval of procurement sources required.

2. Source Inspection - Source inspection shall be required when (a) the necessary inspection and test equipment or required environment is not available at the test facility, (b) articles being procured are at a level of assembly which precludes verification of quality upon receipt or (c) in-process controls have such an effect on the quality of the article that the quality cannot be determined by inspection or tests of the completed articles.

3. Physical/Chemical Test Reports - All procured raw materials shall be accompanied by physical/chemical test reports which establish conformance to the applicable specification requirements.

4. Age Control - Articles for which acceptability is limited by maximum age shall be clearly identified with a manufacture date and expiration date.

5. Packaging and Shipping Instructions - Special packaging, preservation or shipping instructions that may be applicable. Special attention to this item is required when drop shipments or hazardous materials are involved.

6. Inspection and Test Data - Requirements for submission of inspection and/or test records with procured articles.

7. Certificates of Compliance - Supplier certifications of conformance with specification requirements.

8. Serialization/Identification - Requirements for serialization and identification of materials or equipment.

D. Procurement Flow Schematic

See Procedure 4.2

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 4.2	REVISION DATE

SUBJECT:
RECEIVING INSPECTION

I PURPOSE

This QMP describes the methods used for the inspection and test of all procured material, parts and equipment (hereinafter referred to as "material") upon receipt from the supplier.

II BACKGROUND

Purchased material used in the test facility should be subjected to inspection when first received from the supplier to assure that it meets purchase order specifications and that non-acceptable material is precluded from use in the measurement system.

III SCOPE OF APPLICATION

A. All procured materials which influence or are intended for use in mobile source emission testing shall be inspected and tested as necessary to verify their conformity to purchase order specifications and any program requirements.

B. Certain material such as calibration gas mixtures, and analytical instruments require special receiving inspection procedures which are prepared and issued by Quality Assurance.

IV RESPONSIBILITIES AND PROCEDURES

A. Receiving (Material)

1. Checks shipment for count and completeness, prepares Receiving Report and collects all pertinent documentation.

2. Moves all materials and paperwork to Receiving Inspection.

B. Receiving Inspection

1. Inspects incoming materials in accordance with established priorities so that an effective flow of material is assured.

2. Checks the purchase order for special requirements and assures that all of the purchase stipulations have been complied with.

    a. If source inspection is a requirement, verifies that parts and documentation are properly identified and accepted by source inspector.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 3
APPROVED BY:		DATE ISSUED:

IV RESPONSIBILITIES AND PROCEDURES (Continued)

B. Receiving Inspection (Continued)

2. (Continued)

   b. If test data, laboratory reports or certifications of compliance are required, verifies that the appropriate documents have been submitted and that they provide satisfactory evidence of conformance to specification requirements.

   c. Raw materials will be accompanied by test reports and/or physical and chemical analysis reports which will be checked against the applicable material specifications for verification of material quality. Such data must be positively identified to correlate with the raw material submitted.

   d. Materials that are subject to quality degradation with age (limited life items) shall be identified with a tag or stamp indicating the manufacturing date and the expiration date for issue or use.

3. Performs inspection and test operations to verify conformity with applicable specification and purchase order requirements.

   a. Material that has successfully met all applicable receiving inspection criteria shall be identified by applying evidence of acceptance to all material and paperwork.

   b. Material that fails to meet any portion of the applicable receiving inspection criteria shall be rejected on a Rejection Report and forwarded to Quality Assurance for disposition.

C. Quality Assurance

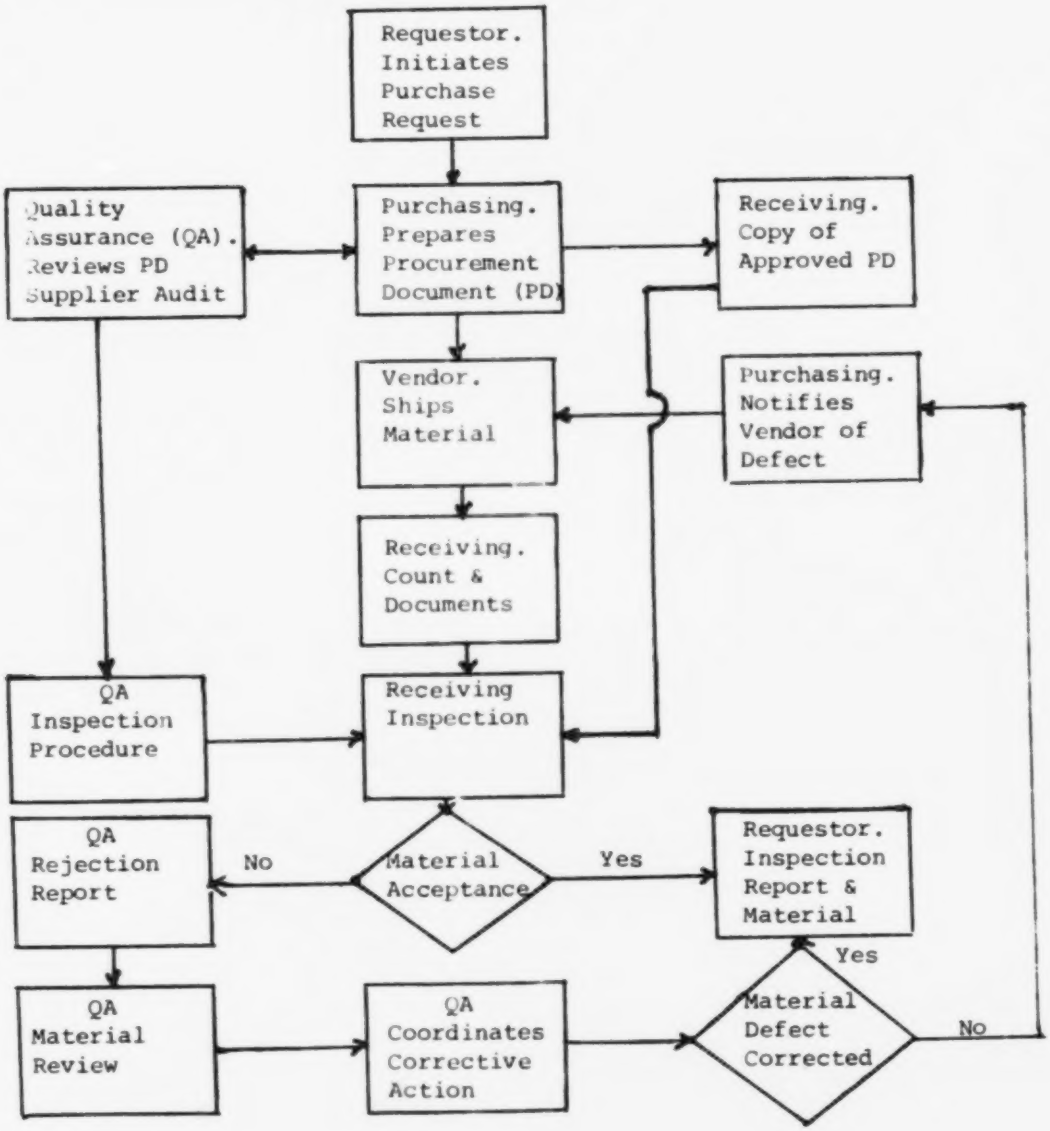
1. Reviews the Rejection Report and coordinates with other organizations as required to establish final disposition of the rejected material.

2. Advises Purchasing of the disposition of the rejected material.

3. Conducts an analysis of any discrepancies/failures that may occur on a first order basis or when indicated by inspection reports.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

D. Procurement Control Flow Schematic


Requestor. Initiates Purchase Request
Quality Assurance (QA). Reviews PD Supplier Audit
Purchasing. Prepares Procurement Document (PD)
Receiving. Copy of Approved PD
Vendor. Ships Material
Purchasing. Notifies Vendor of Defect
Receiving. Count & Documents
QA Inspection Procedure
Receiving Inspection
QA Rejection Report
No
Material Acceptance
Yes
Requestor. Inspection Report & Material
Yes
QA Material Review
QA Coordinates Corrective Action
Material Defect Corrected
No

QUALITY MANAGEMENT PROCEDURES

SECTION 5.0

STANDARDS & CALIBRATION

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EPA QUALITY MANAGEMENT PROCEDURE	QMP NO. 5.1	REVISION DATE

SUBJECT:

EQUIPMENT CALIBRATION AND CYCLE CONTROL

I PURPOSE

This QMP establishes a system that provides for the assignment, accountability and the initial and periodic calibration of all instruments and equipment involved in the performance of mobile source emission testing.

II BACKGROUND

A. The accuracy and adequacy of all equipment used to measure, test or inspect physical or technical aspects of the vehicle or emissions are assured by initial and periodic inspection and calibration of this equipment.

B. The establishment of equipment controls for calibration purposes requires a knowledge of equipment status, usage, location, and the identification of personnel responsible for the equipment.

C. Temporary borrowers of equipment must be indoctrinated regarding their responsibilities for the equipment, specially with regard to calibration status and return of equipment after use.

III SCOPE OF APPLICATION

A. The equipment items requiring initial and periodic calibration for light duty testing are listed below.

Function	Equipment
Receiving & Inspection	1. Tach, dwell, RPM Equipment
	2. Idle exhaust CO/HC meters
	3. Platform scale for vehicle weight
Vehicle Preparation	4. Thermocouples
	5. Temperature Recorders
Vehicle Test	6. Driver's Aid
	7. Constant Volume Sampler
	a. Positive displacement pump
	b. Temperature probe & controller

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III SCOPE OF APPLICATION (Continued)

Function	Equipment
Vehicle Test	c. Pressure measuring device
	d. Counters - Pump RPM
	8. Analytical System
	a. Hydrocarbon Analyzer
	b. Carbon Monoxide Analyzer
	c. Carbon Dioxide Analyzer
	d. Nitric Oxide Analyzer
	e. Recorders and/or Digital Voltmeter
	f. Gas Mixtures
	9. Dynamometer
	10. Barometer
	11. Hygrometer or Psychrometer

Other auxiliary equipment used by a particular laboratory may be subjected to calibration at the discretion of Quality Assurance.

B. All equipment in the standards and calibration accountability control system shall be subject to this procedure.

C. Measurement standards used for calibration purposes shall be traceable to the National Bureau of Standards (NBS) when possible.

D. Calibration gas mixtures used as primary standards shall be traceable to the EPA gravimetric standards and/or the NBS Standard Reference Material.

E. Each organization using the above listed equipment shall be responsible for assuring that instruments are not used beyond the "calibration due" date and for notifying Quality Assurance when inaccuracies or malfunctions occur.

III SCOPE OF APPLICATION (Continued)

F. Calibration control of the instruments in the standards and calibration accountability control system is accomplished through the exclusive use of three documents.

Form No. QMP 7.1 "Loan Order". Identifies the location and person responsible for the equipment. This is not used for "surplus" equipment only but has the primary objective of showing the location of all equipment in the system.

Form No. QMP 7.2 "Calibration Control Card". A keypunch card is used by computer operations to identify when a calibration becomes due. The information on this card is filled in by Records Control each time it is informed of any change in equipment status.

Form No. QMP 7.3 "Calibration Order". A multi-copy form issued by Computer Operations one week in advance of a calibration due date.

Instructions for filling out these forms appears in Section 7.0 of the QMP Manual.

IV RESPONSIBILITIES AND PROCEDURES

A. Equipment Services

a. Performs inspection and calibration of new equipment upon receipt to determine conformance with applicable requirements.

b. Assures that each piece of equipment is identified with a control number for accountability and periodic calibration control.

c. Affixes a distinctive label or tag to each piece of equipment reflecting date of last calibration, by whom it was calibrated and date when it is due for recalibration.

d. Initiates a record in the instrument maintenance log book noting the accomplishment and results of each calibration performed.

e. Transmits to Records Control a Calibration Control Card (Form No. QMP 7.2) containing equipment control number, description, location and recalibration date information for accountability and calibration control records.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

B. Equipment Services (Equipment Stores)

1. Stores equipment carefully to prevent damage, corrosion or contamination.

2. Issues equipment only upon receipt of a properly completed Instrument Loan Order (QMP Form No. 7.1) and distributes copies as follows:

    a. Copy number 3 to assignee

    b. Copy number 2 to file

    c Copy number 1 to records control

3. Files copy number 1 in control number order when returned by records control.

4. When equipment is returned as no longer needed by the assignee, stamps #1 and #2 copies as "received", gives #1 copy to assignee and forwards the #2 copy to Standards and Calibration (Records Control).

5. Maintains available inventory file by control number and status.

C. Standards and Calibration (Record Control)

1. Submits initial Calibration Control Card to Computer Operations.

2. Upon receipt of Instrument Loan Order copy noting loan or return of equipment, enters location changes on a new Calibration Control Card for equipment affected and forwards to Computer Operations.

3. Destroys the #2 copy after processing location change.

D. Computer Operations

1. Sorts calibration control data file weekly for items due for recalibration the following week.

2. Prints calibration orders (QMP Form No. 7.3) for recall of items for recalibration and delivers to Standards and Calibration (Records Control).

IV RESPONSIBILITIES AND PROCEDURES (Continued)

E. Standards and Calibration (Records Control)

1. Remove the follow-up copy of the calibration order(s) and forward to Standards and Calibration (Equipment Stores).

2. Forward the remaining copies (3) of the calibration orders(s) to the using organization(s).

F. Using Organization

1. Completes signature, extension (telephone) and indicates in the appropriate "yes-no" blocks on the calibration order whether or not the equipment is to be returned to the user after calibration.

2. Removes and retains the receipt copy of the calibration order.

3. Attaches the remaining two copies of the calibration order to the equipment and returns equipment to Standards and Calibration (Equipment Stores).

G. Standards and Calibration (Equipment Stores)

1. Files follow-up copies of the calibration order according to due date. Notify Quality Assurance when calibration is past due.

2. Removes the follow-up copy of calibration order from file when equipment with traveler and record copies of calibration order is received for scheduled recalibration.

3. If a replacement item is furnished from Equipment Stores note this information in the "Remarks" block on the traveler and record copies of the calibration order.

4. If "no" return block is checked or replacement item furnished, process instrument loan order as in IV B.

H. Equipment Services (Calibration and Maintenance Technician)

1. Calibrate equipment per applicable instructions and affix calibration label or tag with stamp and date entries to the equipment.

2. Record results of calibration on the traveler and record copies of the calibration order.

3. Discard follow-up copy of calibration order, forward record copy to Standards and Calibration (Records Control) and forward traveler copy with equipment to Equipment Stores.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

I. Standards and Calibration (Records Control)

1. Notes the changes on a calibration control card from information on the record copy of the calibration order.

2. Forwards the calibration control card with changes to Computer Operations and files record copy of the calibration order in the equipment history file.

   NOTE: Refer calibration orders indicating "out of tolerance" information to assigned personnel for evaluation prior to filing. Assigned personnel review the history file of instruments found to be "out of tolerance" to identify critical and chronic conditions peculiar to the instrument or common to all instruments of that type.

   a. Corrective action must be taken to prevent recurrence of "out of tolerance" conditions; i.e., reduce the calibration interval for the item(s) affected, revise the calibration checklist affected to improve the method of calibration, utilize more accurate standards and/or include preventive maintenance requirements, dispose of the items affected, etc.

   b. Record completion of review and evaluation by entries in applicable blocks of the calibration order.

J. Computer Operations

1. Keypunch and print new calibration control card incorporating changes.

2. Return old and new calibration control cards to Standards and Calibration (Records Control).

K. Standards and Calibration (Equipment Stores)

1. Return calibrated equipment with the traveler copy of the calibration order to the user.

   NOTE: If the calibration order indicates that a return instrument was not required or a replacement was furnished, place the equipment in Stores. Forwards the traveler copy of the calibration order to the user in those instances where the equipment affected was found to be out of tolerance.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

L. Quality Assurance

1. Conducts follow-up of equipment not returned for calibration by due date, places an "out of service" tag on equipment, and maintains follow-up to assure that equipment is not used again until re-calibrated.

2. Maintains surveillance on an audit basis of the proper calibration status of test and measuring equipment.

M. Equipment Services

1. Repair

   a. Performs repair/recalibration of equipment submitted due to failure or damage in use.

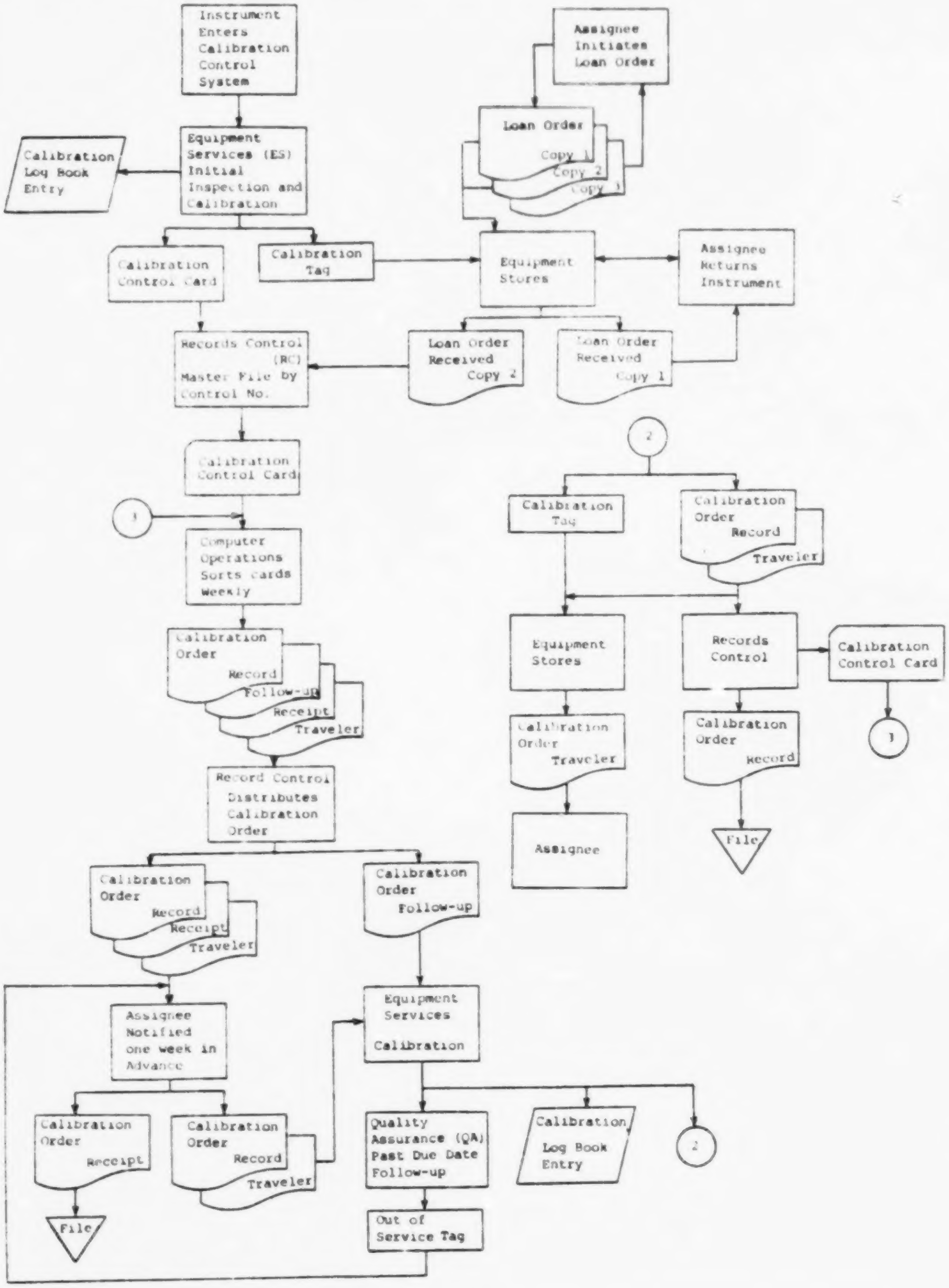
   b. Initiates and files record of repair/recalibration accomplished.

   c. Transmits to Data Processing the new due date for recalibration.

   d. Returns the repaired/recalibrated equipment to the submitting organization, if return was requested.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

N. Flow Schematic - Equipment Calibration Control


Instrument Enters Calibration Control System
Assignee Initiates Loan Order
Calibration Log Book Entry
Equipment Services (ES) Initial Inspection and Calibration
Loan Order
Copy 1
Copy 2
Copy 3
Calibration Control Card
Calibration Tag
Equipment Stores
Assignee Returns Instrument
Records Control (RC) Master File by Control No.
Loan Order Received Copy 2
Loan Order Received Copy 1
2
Calibration Control Card
Calibration Tag
Calibration Order Record Traveler
1
Computer Operations Sorts cards weekly
Equipment Stores
Records Control
Calibration Control Card
Calibration Order Record Follow-up Receipt Traveler
Calibration Order Traveler
Calibration Order Record
1
Record Control Distributes Calibration Order
Assignee
File
Calibration Order Record Receipt Traveler
Calibration Order Follow-up
Assignee Notified one week in Advance
Equipment Services Calibration
Calibration Order Receipt
Calibration Order Record Traveler
Quality Assurance (QA) Past Due Date Follow-up
Calibration Log Book Entry
2
File
Out of Service Tag

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 5.2	REVISION DATE

SUBJECT:

CALIBRATION INSTRUCTION DOCUMENT MAINTENANCE

I PURPOSE

This QMP specifies the procedure for the acquisition, use and maintenance of calibration instruction documents.

II BACKGROUND

A. Documentation of the calibration procedures used by standards and calibration is necessary to assure that the correct calibration procedure is used for a particular instrument, and to provide a reference source when the calibration of an instrument is questioned.

B. Uncontrolled calibration documents have a tendency to disappear or be unavailable when needed. It is therefore, of utmost importance that these documents be kept in a central controlled file.

III SCOPE OF APPLICATION

A. All documents, i.e., manufacturer manuals, calibration checklists, procedures providing methodology for calibrating or repairing specific types of equipment shall be subject to this procedure.

IV RESPONSIBILITIES AND PROCEDURES

A. Standards and Calibration

1. Provides adequate information for calibration and repair of equipment submitted for initial calibration.
2. Obtain manuals or procedures needed from reliable source(s); i.e., manufacturer, government agency, professional society, etc.
3. Initiates Calibration Checklists/Reports defining specific scope and method of calibration and maintenance when practical or necessary.
4. Establishes and maintains files of all documents.
5. Checks out and utilizes applicable documents to conduct calibration or repair of equipment.
6. Returns documents to file immediately upon completing calibration or repair of equipment.

CONCURRENCES	DATE	IMPLEMENTATION
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IV RESPONSIBILITIES AND PROCEDURES (Continued)

B. Equipment Services

1. Forwards all information bulletins, calibration and maintenance manuals etc., to standards and calibration for review and filing upon receipt of a "new-order" instrument.

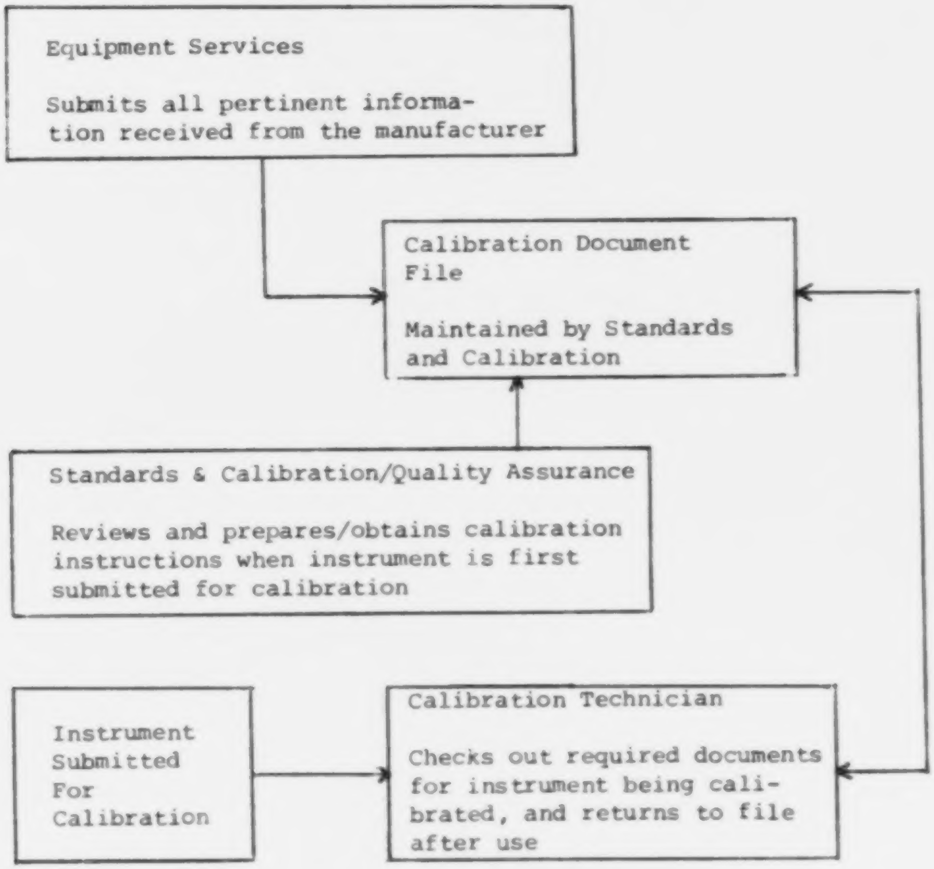
C. Quality Assurance

1. Assists standards and calibration in review and preparation of calibration procedures, forms, etc.

2. Maintains surveillance on an audit basis to assure correct use of calibration documents and that proper control procedures are being maintained.

IV RESPONSIBILITIES AND PROCEDURES

D. Flow Schematic - Calibration Instruction Document Maintenance


Equipment Services
Submits all pertinent information received from the manufacturer
Calibration Document File
Maintained by Standards and Calibration
Standards & Calibration/Quality Assurance
Reviews and prepares/obtains calibration instructions when instrument is first submitted for calibration
Instrument Submitted For Calibration
Calibration Technician
Checks out required documents for instrument being calibrated, and returns to file after use

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 5.3	REVISION DATE

SUBJECT:

CALIBRATION INTERVALS

I PURPOSE

This QMP describes the procedure for establishing realistic calibration intervals to maintain prescribed accuracy of all measuring and test equipment.

II BACKGROUND

A frequency distribution chart for determining calibration intervals is presented in Attachment No. 1, which may be used to adjust calibration intervals of a specific model after the evaluation of a minimum of one year's calibration results or twenty (20) calibration results, whichever occurs first.

III SCOPE OF APPLICATION

All measuring and test equipment used in conjunction with emission testing operations shall be subjected to the requirements of this procedure.

IV RESPONSIBILITIES AND PROCEDURES

A. Standards and Calibration

1. Establishes the calibration interval for each piece of equipment (based upon its stability, reliability, usage and calibration history of identical or similar equipment), at the time it is submitted for initial calibration.

2. Enters the calibration interval in the applicable block of the Calibration Order (QMP Form No. 7.3) before forwarding with the equipment to Calibration for initial acceptance.

3. Transmits the calibration interval information for each piece of equipment to Computer Operations using the Calibration Control Card (QMP Form No. 7.2).

4. Periodically (minimum each 12 months) evaluates the calibration history of equipment, by manufacturer and model, to determine if an adjustment of calibration interval is needed.

   a. Utilize the attached chart based upon the percent of times equipment has been out of tolerance when submitted for scheduled recalibration.

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IV RESPONSIBILITIES AND PROCEDURES (Continued)

A. Standards and Calibration (continued)

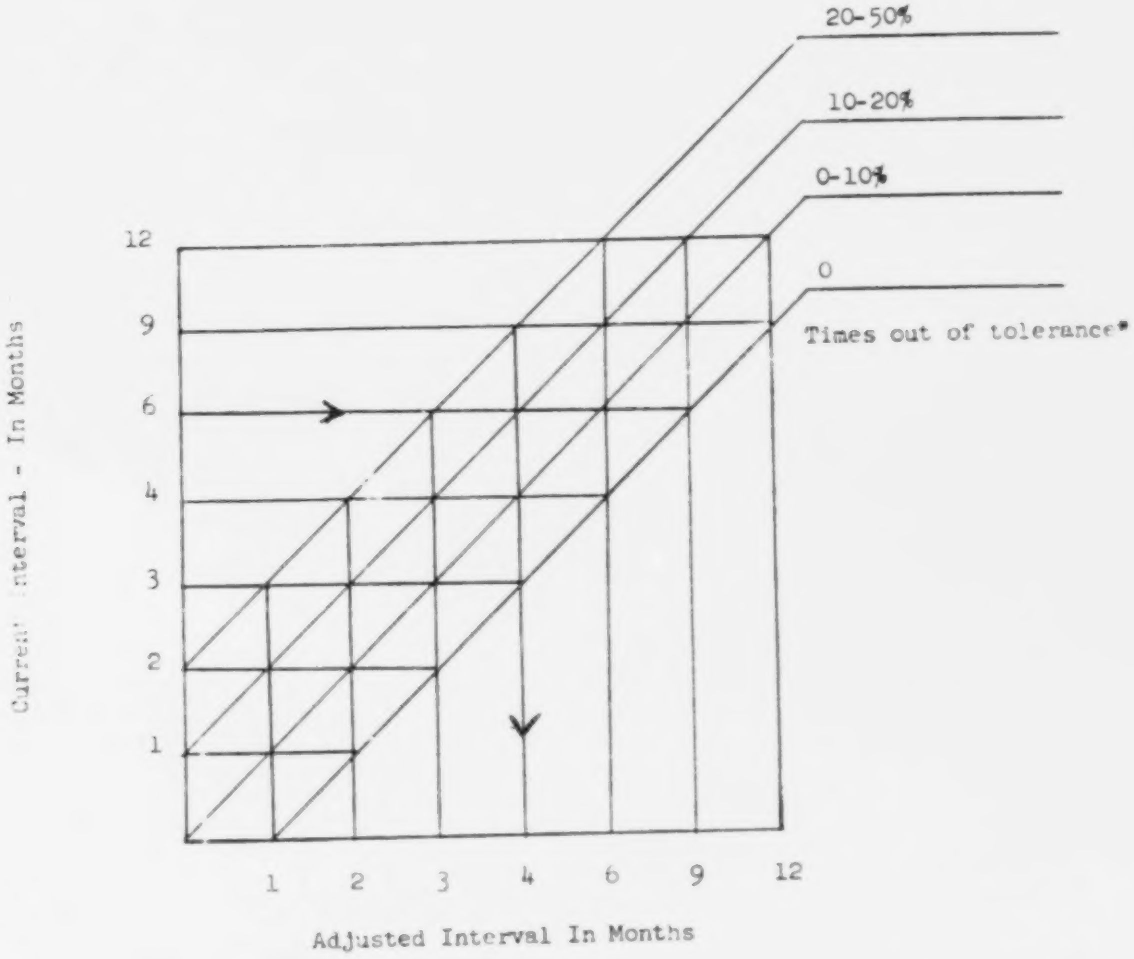
b. Adjust calibration interval when needed and transmit information to Data Processing to change affected Calibration Control Card(s) (QMP Form No. 7.2).

NOTE: The calibration interval for any item can be extended only when its history for the past year shows zero (0) "times out of tolerance".

5. Initiates action to dispose of or replace individual pieces of equipment with a history of poor reliability or uneconomical maintenance cost.

OUT OF TOLERANCE FREQUENCY DISTRIBUTION CHART

*This chart shall be used for adjusting the calibration interval of a specific model of test equipment only after the evaluation of a minimum of one year's calibration results or twenty (20) calibration results, which ever occur first.



Example of Chart Usage:

1. Current Interval - six (6) months

2. Percent Out of Tolerance - eighteen percent (18%)

3. Follow six (6) month current interval line to intersection of (10-20%) line. Read down vertical line to adjusted interval of four (4) months. This establishes a new base interval of four (4) months.

EPA QUALITY MANAGEMENT PROCEDURE

QMP NO.	REVISION DATE
5.4	

SUBJECT: CALIBRATION STANDARDS

I PURPOSE

This QMP prescribes the requirements for establishing and controlling standards used to determine the accuracy of emission test systems.

II BACKGROUND

A. The continuous validity of test variables is dependent upon sequential comparisons of equipment accuracy with known standards of progressively higher orders of precision.

B. As a goal, standards used to calibrate other equipment are to have accuracies of at least 4 times better than that of equipment to be calibrated.

C. Definitions: The nomenclature and definitions used among emission laboratories varies widely, therefore, the standards discussed in this procedure are defined below:

Measuring and Test Equipment - Measuring and sensing devices used to establish specifications or determine the acceptability of processes or data.

Transfer Standards - Measuring and sensing devices having accuracies directly traceable to Reference Standards.

Reference Standards - Measuring and sensing devices having the highest order of accuracy in the calibration system.

III PROCEDURE

A. Standards and Calibration

1. Establish Reference and Transfer Standards having accuracy, stability and range which are compatible with test specification requirements.

2. Establish and maintain intervals for recalibration of Reference and Transfer Standards based upon stability, reliability, intended usage and calibration history of the equipment.

3. Use Reference and Transfer Standards in an atmosphere controlled as necessary, to assure accuracy of measurements and to prevent contamination or corrosion.

CONCURRENCES	DATE	IMPLEMENTATION
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III PROCEDURE (Continued)

A. Standards and Calibration (continued)

4. Maintain records certifying that the calibrations of Reference Standards are traceable to the National Bureau of Standards, or have been derived from accepted values of physical constants, or have been derived by ratio type of self-calibration techniques.

QUALITY MANAGEMENT PROCEDURES

SECTION 6.0

LABORATORY OPERATIONS

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EPA QUALITY MANAGEMENT PROCEDURE	QMP NO. 6.1-HD	REVISION DATE

SUBJECT:

HEAVY DUTY TEST OPERATIONS

I PURPOSE

This QMP establishes the functions to be performed during mobile source emission testing to ensure the quality and validity of the data generated during the test.

II BACKGROUND

A. Specific detailed procedures for performing emission tests are outlined in the Test Procedure Manual. It is also necessary to outline the responsibilities and interrelationships of Test Operations and Quality Assurance by generating a QMP.

B. Certain quality functions are necessary to ensure the precision and accuracy of the data generated by the measurement system. Quality Assurance has the responsibility of determining that these functions achieve the desired level of precision and accuracy within the capability of the measurement system.

III SCOPE OF APPLICATION

A. All phases of Heavy-Duty Engine emission testing shall be subject to definitive Quality Assurance provisions on both a scheduled and audit basis.

B. Data generated during each sequential test phase shall be documented and validated prior to start-up of next test sequence.

C. Any deficiencies encountered during the testing operations shall be fully documented, investigated and corrected to preclude their reoccurrence.

IV RESPONSIBILITIES AND PROCEDURES

A. Test Operations

1. Prepares, implements and revises the Test Procedure Manual, which details the procedures to be used in Heavy-Duty Engine emission testing.

2. Assures that the procedures are being correctly followed and that the technician has the required skill and knowledge to perform his assigned tasks, by implementing evaluation and training programs.

3. Schedules engine for test and subsequent return to the manufacturer.

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IV RESPONSIBILITIES AND PROCEDURES (Continued)

B. Receiving Inspection

1. Receives and inspects the scheduled engine and completes the vehicle receiving inspection documentation.

C. Data Validation

1. Verifies accuracy and satisfactory completion of engine receiving inspection and required installation specifications and equipment.

D. Heavy Duty Engine Testing

1. Installs engine test bed on engine dynamometer.
2. Attaches fuel lines, thermocouples, air flow devices, etc. as required.
3. Verifies that proper amount and type of fuel is used.
4. Performs engine preconditioning checks, engine performance checks, engine preconditioning test and completes applicable preconditioning reports.

E. Data Validation

1. Verifies that all elements of the preconditioning requirements have been satisfactorily and accurately completed and authorizes engine to next test function.

F Heavy Duty Engine Testing

1. Performs smoke test on all heavy duty diesel engines. Tests according to procedures contained in subpart I of the Federal Regulations and the Laboratory Test Procedure Manual.
2. Performs the 13-mode gaseous emission test cycle for all diesel engines and the 9-mode cycle for all gasoline powered engines.
3. Performs sample analysis in accordance with prescribed procedure and documents all data, including ambient conditions and instrument operating parameters.
4. Submits all documentation to data validation.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

G. Data Validation

1. Checks all data for completeness and accuracy and forwards to Data Services for preliminary processing.

H. Quality Assurance

1. Maintains continual surveillance over the functions associated with the performance of all phases of the heavy duty engine emission testing program.
2. Assures proper and current calibration of instruments and equipment used in heavy duty engine testing.
3. In the event of a test failure, whether instrument, dynamometer operator, or engine, prepares a Test Condition Report to describe the nature of the problem, and coordinates with other organizations to assure that expedient corrective action is taken.
4. Performs audits and correlation studies of test operations to ensure the reliability and accuracy of the data.
5. Submits reports of data and failure analyses to Management and Laboratory Operations.

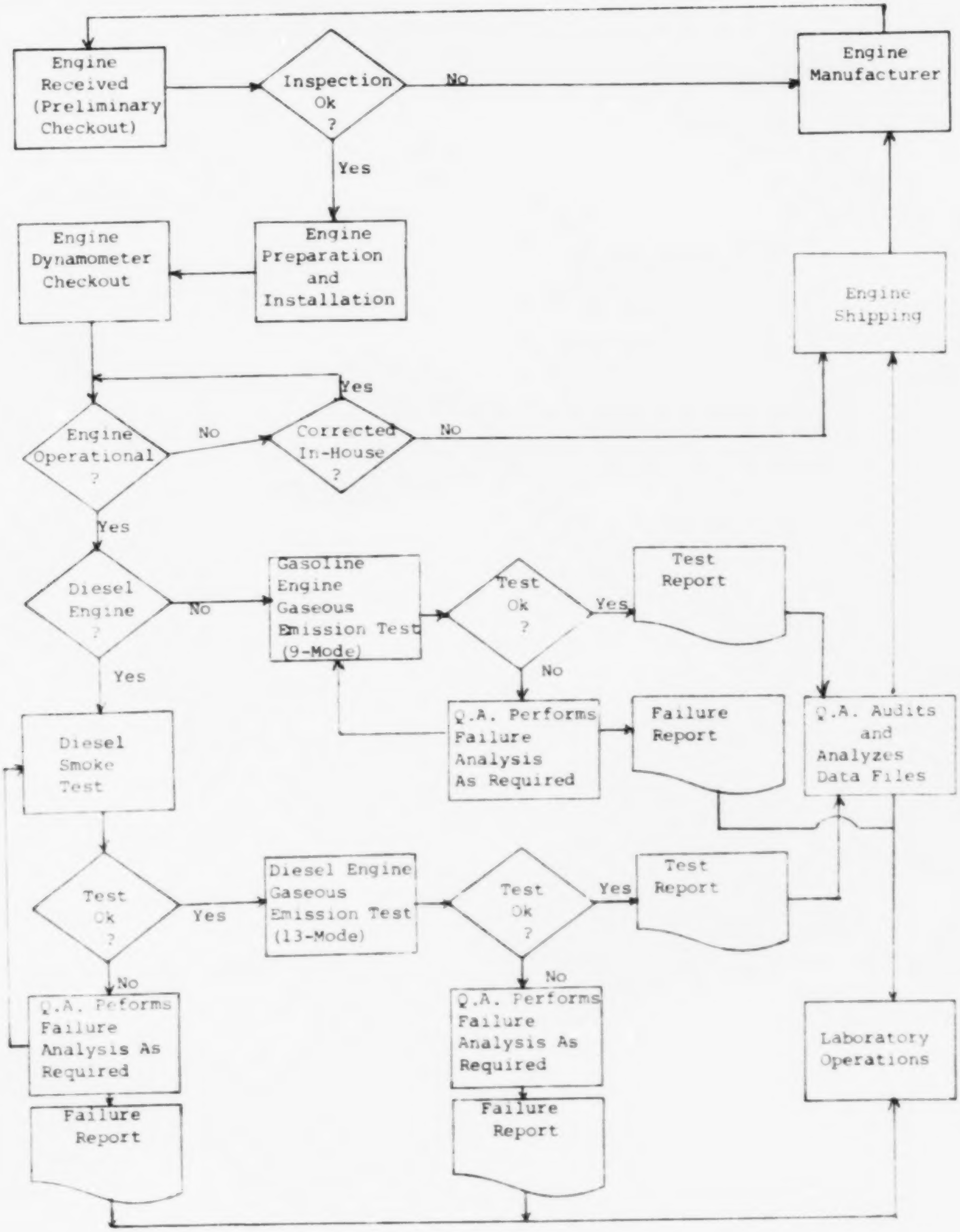
I. Data Validation

1. Checks all submitted data and heavy duty engine information for completeness and accuracy.
2. Forwards all data to Data Services for final processing.

J. Heavy-Duty Testing/Shipping

1. After satisfactory completion of all tests and restoration of the engine to the "as received" condition, completes shipping order and returns engine to the manufacturer/owner.

K. HEAVY DUTY TEST FLOW SCHEMATIC


Engine Received (Preliminary Checkout)
Inspection Ok ?
No
Engine Manufacturer
Yes
Engine Dynamometer Checkout
Engine Preparation and Installation
Engine Shipping
Yes
Engine Operational ?
No
Corrected In-House ?
No
Yes
Diesel Engine ?
No
Gasoline Engine Gaseous Emission Test (9-Mode)
Test Ok ?
Yes
Test Report
No
Yes
Diesel Smoke Test
Q.A. Performs Failure Analysis As Required
Failure Report
Q.A. Audits and Analyzes Data Files
Test Ok ?
Yes
Diesel Engine Gaseous Emission Test (13-Mode)
Test Ok ?
Yes
Test Report
No
No
Q.A. Peforms Failure Analysis As Required
Q.A. Performs Failure Analysis As Required
Laboratory Operations
Failure Report
Failure Report

EPA QUALITY MANAGEMENT PROCEDURE

QMP NO.	REVISION DATE
6.2	

SUBJECT: COORDINATION AND IMPLEMENTATION OF EQUIPMENT OR PROCEDURE CHANGE NOTICES

I PURPOSE

This Quality Management Procedure (QMP) describes the procedure for originating, coordinating, and implementing changes in practices or equipment specified in the Testing Procedures (TP) used in the Mobile Source Emission Measurement Program (MSEMP).

II BACKGROUND

A. Quality in the MSEMP is dependent upon strict adherence to prescribed procedures and equipment configuration as defined in the Test Procedures and the Federal Register.

B. This QMP provides three functions -

1. A means to revise or improve prescribed procedures, with documented control of any such changes.
2. A mechanism to control changes made to equipment used in the test facility.
3. A formal method of introducing Federal Register revisions into the EPA Test Procedures.

III SCOPE OF APPLICATION

A. The general scope of application of the equipment and procedures change notice (EPCN) is the area of Laboratory Operations including Test Operations, Support Operations, and Test Scheduling. An EPCN may be originated by any department manager or team leader.

B. The EPCN may also be originated by Quality Assurance or other functional groups.

C. All EPCNs are to be implemented using QMP Form No. 7.5 shown in Section 7.5 of the forms instruction.

IV RESPONSIBILITIES AND PROCEDURES

A. Originator of EPCN

1. Drafts the EPCN using QMP Form No. 7.5 and submits it to Laboratory Operations.
2. Maintains a copy of the original draft EPCN for record and follow-up.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 3
APPROVED BY:		DATE ISSUED:

IV RESPONSIBILITIES AND PROCEDURES (Continued)

A. Originator of EPCN (continued)

3. Makes major revisions to the draft EPCN as requested by reviewers and resubmits to Laboratory Operations.

B. Laboratory Operations

1. Determines the areas affected and indicates the distribution of the draft EPCN.
2. Submits draft EPCN to Document Control for assignment of EPCN number and distribution to the affected departments for review and comment.
3. Reviews comments on the draft EPCN and makes decision to return to the originator for revision or determines that the draft EPCN should be implemented.
4. Determines effective date(s) of change implementation and maintains EPCN file.
5. Obtains required approvals necessary for implementation of EPCN.
6. Approved EPCN is forwarded to Document Control for formal implementation of change.

C. Quality Assurance

1. Reviews draft EPCN for incorporation of quality provisions and acceptance criteria, and adequate equipment specifications and blue prints and/or schematic diagrams in procedural/equipment changes specified in EPCN.
2. Forwards draft EPCN to Laboratory Operations with recommendations.
3. Performs procedure or equipment audit to assure implementation by the effective date, and incorporation of adequate quality provisions in revised documents.

D. Document Control

1. Assigns EPCN number and distributes draft EPCN to reviewers as prescribed by Laboratory Operations and maintains the originals in a file by numerical sequence.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

D. Document Control (continued)

2. Implements required changes to prescribed procedures/equipment configuration and maintains appropriate records of these changes.

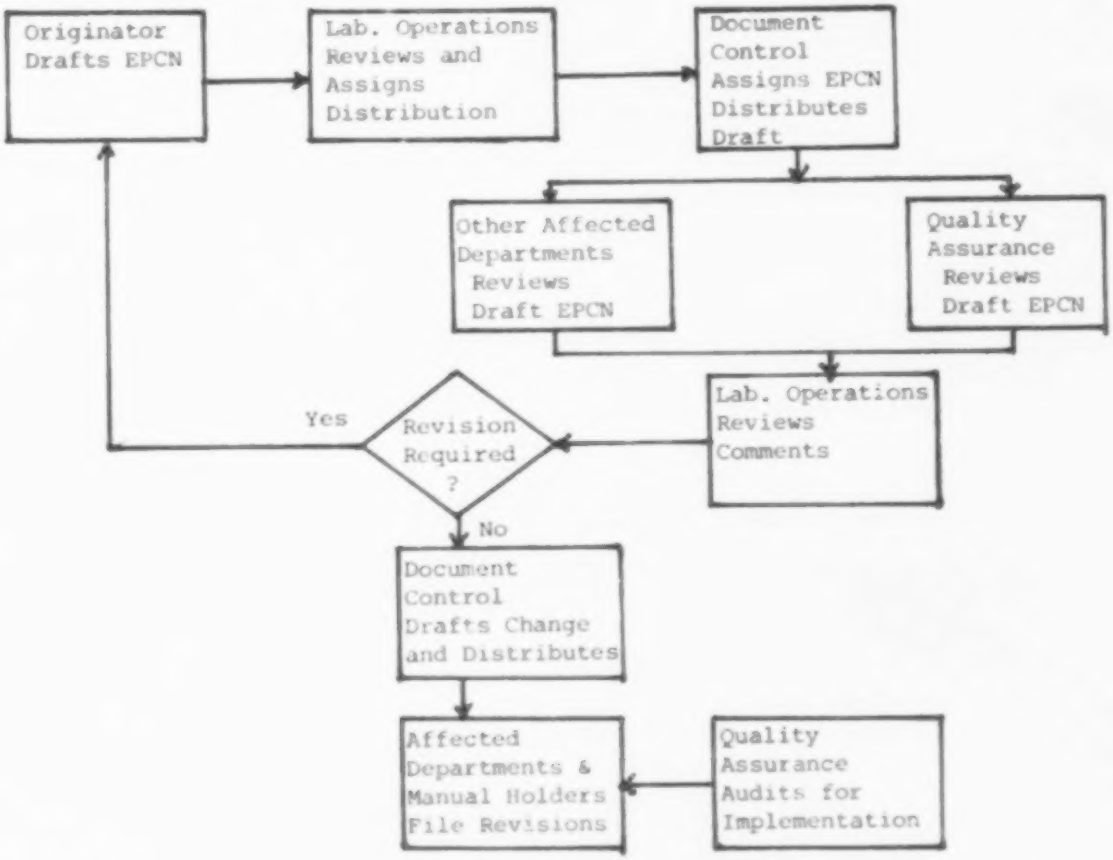
3. Distributes revised procedures together with copy of EPCN authorizing change, to all Procedure Manual holders.

4. Distributes copies of EPCN's affecting equipment configuration changes together with revised documentation to departments/personnel affected by the change.

E. EPCN Reviewer

1. Comments on, approves or disapproves of the EPCN. Suggests appropriate revisions and returns to Laboratory Operations in a timely manner.

F. EPCN Flow Schematic


Originator Drafts EPCN
Lab. Operations Reviews and Assigns Distribution
Document Control Assigns EPCN Distributes Draft
Other Affected Departments Reviews Draft EPCN
Quality Assurance Reviews Draft EPCN
Lab. Operations Reviews Comments
Revision Required ?
Yes
No
Document Control Drafts Change and Distributes
Affected Departments & Manual Holders File Revisions
Quality Assurance Audits for Implementation

EPA QUALITY MANAGEMENT PROCEDURE	QMP NO. 6.3-HD	REVISION DATE

SUBJECT:

TEST ENGINE FUEL CONTROL

I PURPOSE

This QMP establishes the requirements for the control of fuel used in the performance of a Heavy Duty Engine Emission Test.

II BACKGROUND

A. Fuels used in the performance of a test must meet Federal Register specifications. The composition and characteristics of the fuel used for an emission test can affect the data and make a test invalid. Some of the 1975 engines may be equipped with catalyst devices which become inoperative if fuels containing lead additives are used. Therefore, it is of utmost importance that responsibilities are designated for the controlled use of fuel, and that procedures and equipment are designed to prevent the use of incorrect fuel in an emission test engine.

B. Storage and handling of these fuels must be controlled since such specifications as the Reid vapor pressure can change during storage or transfer of the fuel. Contamination of fuels with undesirable components such as lead or additives should be avoided since this may have detrimental effects on engines and emissions control systems. Storage tanks cannot be pumped "dry" so there is always some residual fuel left in the tank, and frequently water and sludge collect in the bottom of the tanks. Historical records of fuel storage facilities must be kept up to date, tanks should be used only for fuels of the same specifications and periodic examination of storage tanks must be conducted.

C. Procurement control of the fuels used in the testing facility is also critical and the responsibilities and procedures for purchasing, receiving, and inspecting fuels must be detailed.

III SCOPE OF APPLICATION

A. This procedure generally applies to any fuel used in the test facility but specifically to the leaded (Indolene 30) and unleaded (Indolene HO) gasoline, Type 1-D and 2-D diesel fuels used in the emission test.

B. Leaded fuel must not be used in engine equipped with catalyst devices.

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IV RESPONSIBILITIES AND PROCEDURES

A. Purchasing

1. Indicates Federal Register fuel specifications on purchase order and obtains approval of Quality Assurance. Requests batch analysis from the vendor. Specifies ASTM or other method for analysis of specified characteristics.

2. Fuels other than those required by the Federal Register or not clearly specified, such as the fuels used for durability or emission data vehicles, must be clearly specified and approved by Quality Assurance.

B. Quality Assurance

1. Reviews procurement documents for all fuel used in the test facility.

2. Specifies, approves ASTM or other methods for analysis of fuel characteristics.

3. Develops, details and implements procedures for fuel inspection and monitoring programs.

4. Receives copies of all fuel analysis reports and releases fuel that meets specifications to the testing operations.

5. Reports any discrepancies found in the fuel specifications analyses to Purchasing and supplier. Determines final disposition of the fuel and assures that it has not been and will not be used in any test vehicle.

6. Coordinates corrective action with Purchasing and Test Operations when necessary to ensure uninterrupted availability of correct test fuels.

C. Receiving

1. Checks batch number against batch analysis. Checks batch analysis to confirm compliance with purchase order specifications.

2. Obtains sample of fuel from all bulk shipments in rinsed one gallon container and forwards to chemical analysis.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

D. Chemical Analysis

1. Analyzes all received fuel for lead phosphorous and sulphur content. Unleaded fuels shall not be released for use until lead content is verified to be within specifications. Diesel fuels-flash point, distillation curve, and total sulphur are commonly determined "in-house."

2. Determines that fuel meets specifications either by analysis "in-house" or by independent test laboratory.

3. Prepares detailed laboratory procedures for "in-house" fuel analysis and obtains Quality Assurance approval.

4. Removes fuel sample from bulk storage containers monthly for analysis, and reports data to Laboratory Operations and Quality Assurance.

5. Monitors all fuel storage areas for proper environmental control.

E. Test Scheduling

1. Stamps fuel requirements, clearly, on all work sheets and check lists associated with each test engine.

F. Heavy Duty Engine Testing

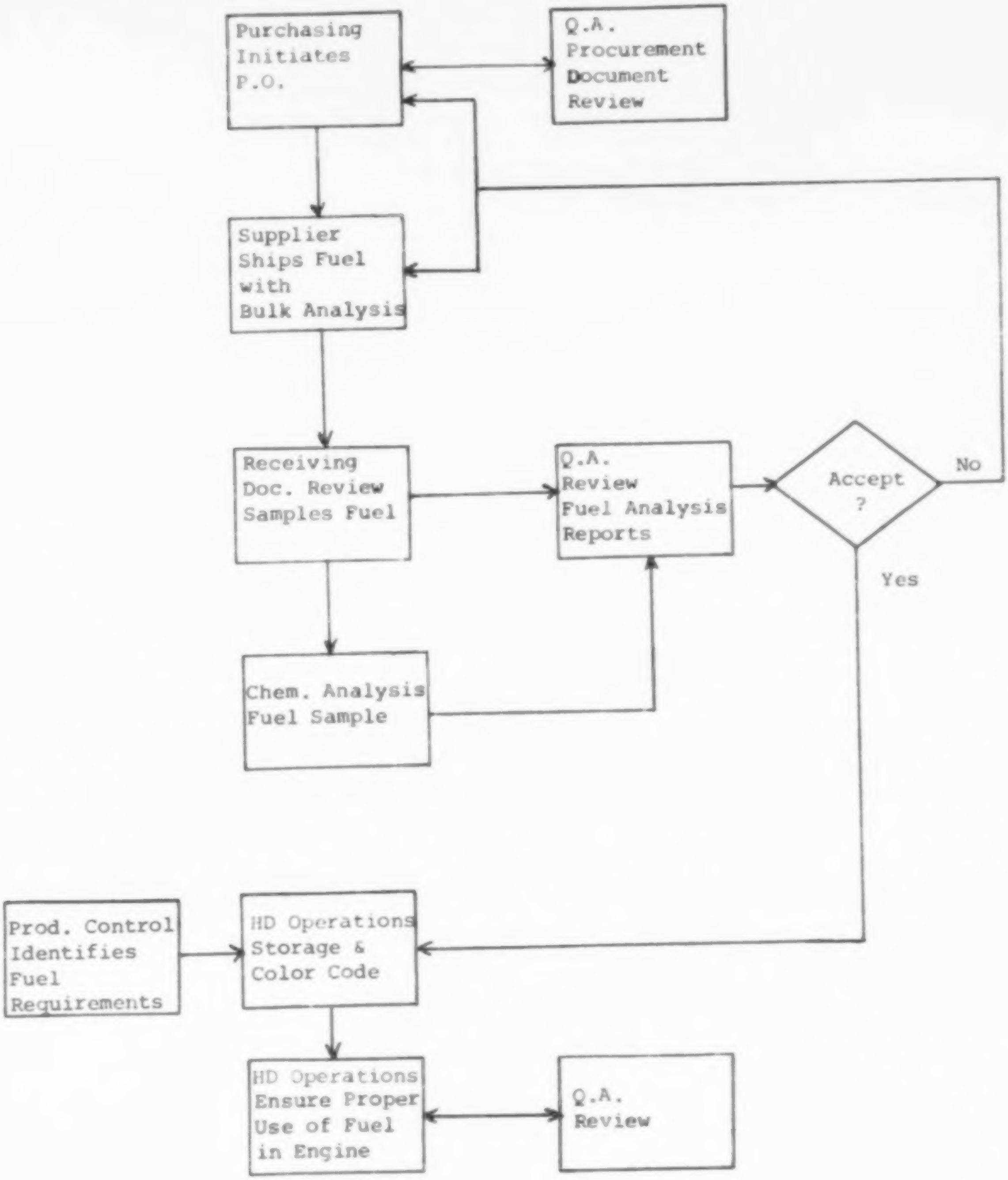
1. Verifies the type of fuel required and the nozzle configuration used for each type of fuel. Place appropriate color coding on pumps, containers, fuel conditioning equipment, bulk fuel lines and vehicles to clearly identify the correct fuel.

2. Trains technicians in the proper handling, storage, transferring of fuels and color coding of vehicles to ensure engine fuel requirements are met.

3. Maintains vehicle fueling logs including the vehicle identification number, type of fuel, number of gallons dispensed, and signature of technician and witness.

IV **RESPONSIBILITIES AND PROCEDURES** (Continued)

G. Test Engine Fuel Control Flow Schematic


Purchasing Initiates P.O.
Q.A. Procurement Document Review
Supplier Ships Fuel with Bulk Analysis
Receiving Doc. Review Samples Fuel
Q.A. Review Fuel Analysis Reports
Accept ?
No
Yes
Chem. Analysis Fuel Sample
Prod. Control Identifies Fuel Requirements
HD Operations Storage & Color Code
HD Operations Ensure Proper Use of Fuel in Engine
Q.A. Review

EPA QUALITY MANAGEMENT PROCEDURE

QMP NO.	REVISION DATE
6.4	

SUBJECT:
TEST VEHICLE SCHEDULING

I PURPOSE

This procedure establishes the requirements attendant to the scheduling of vehicle testing operations.

II BACKGROUND

A. The orderly and timely performance of mobile source emission testing dictates the need for identifying the responsibilities and procedures for scheduling these tests.

B. Scheduling and timely reporting of the projected testing load to Vehicle Test is necessary for organization and planning of future test requirements.

III SCOPE OF APPLICATION

A. All requests for emission test and retests must be submitted with proper authorization to Production Control.

B. Production Control notifies Laboratory Operations and Vehicle Test of the test schedule on a daily, weekly and monthly basis.

IV RESPONSIBILITIES AND PROCEDURES

A. Production Control

1. Upon receipt of a Test Request from the Certification and/or other divisions:

   a. Determines the type(s) of test required.

   b. Determines equipment and facility availability.

   c. Establishes priority based on test program requirements.

2. Schedules the test and sends notification of date and time to the requester.

3. Prepares a weekly test schedule summary for submission to Laboratory operations a week prior to the scheduled testing, and requires notification of concurrence with the test schedule no later than the last working day of that week.

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IV RESPONSIBILITIES AND PROCEDURES (Continued)

A. Production Control (continued)

4. Submits daily test schedules to Test Operations on the day preceding scheduled tests.

5. Prepares yearly projections (updated monthly) for Testing Operations and the Laboratory.

6. Receives test vehicles and ships them (after notification of test validity) upon authorization obtained on the Receiving and Shipping order.

7. Schedules vehicles for retest at the earliest possible date, when original test is declared invalid and an authorized request for retest is received.

B. Vehicle Test

1. Submits authorized requests for retest of vehicles invalidated for any reason together with a description of test priority requirements.

2. Informs Production Control of scheduled "down time" of test cells and immediately informs Production Control of unscheduled "down time" and the expected start up date and time. Keeps Production Control informed of test cell status on a daily basis.

C. Test Operations

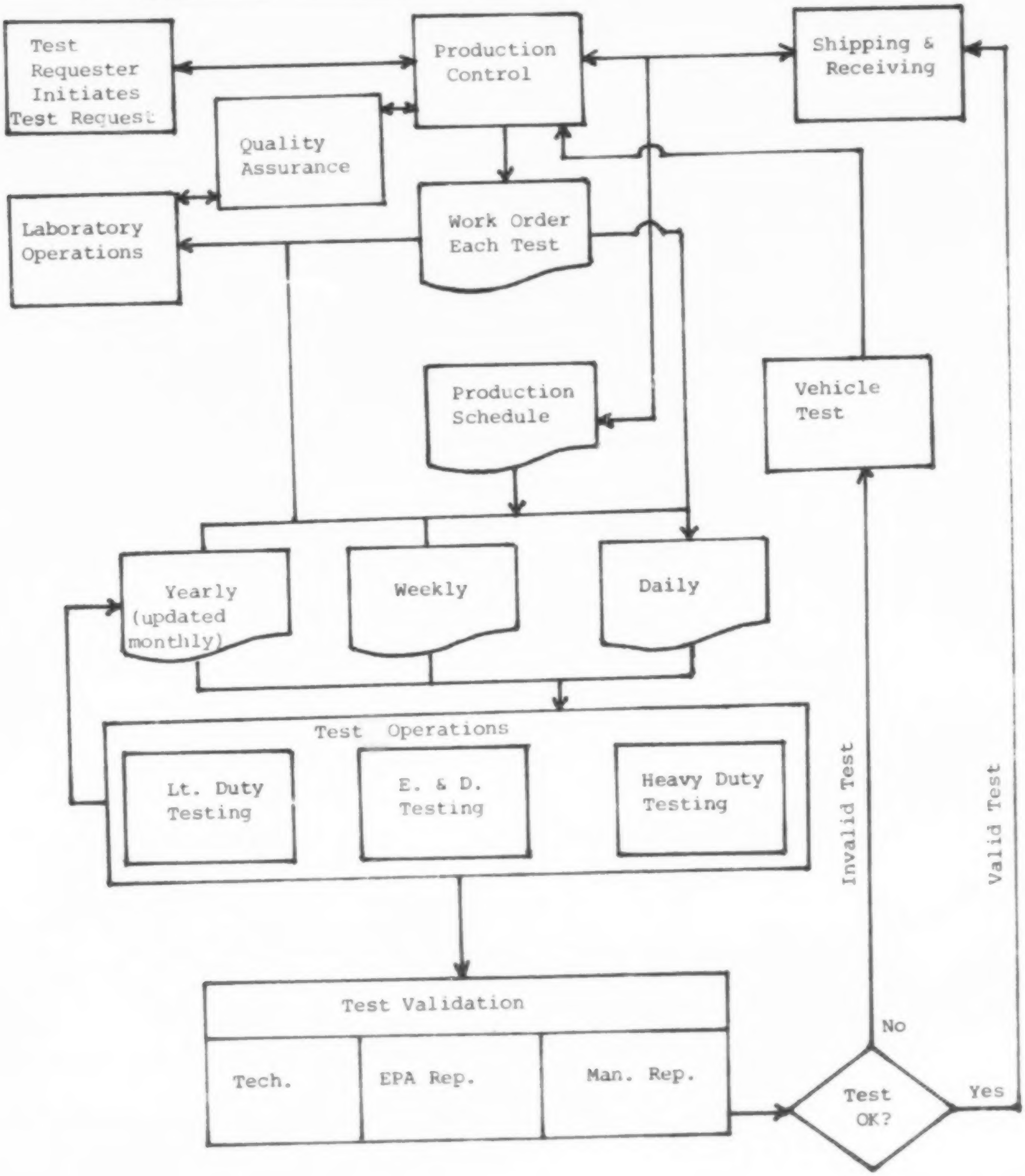
1. Authorizes, submits and monitors the projected test scheduling on a monthly basis. Submits projected annual test loads and develops and implements plan for meeting these requirements.

D. Quality Assurance

1. Assists Production Control and Laboratory Operations in developing efficient programs for meeting future commitments, with the implementation of specific quality requirements where necessary.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

E. Typical Scheduling Flow Schematic


Test Requester Initiates Test Request
Production Control
Shipping & Receiving
Quality Assurance
Laboratory Operations
Work Order Each Test
Production Schedule
Vehicle Test
Yearly (updated monthly)
Weekly
Daily
Test Operations
Lt. Duty Testing
E. & D. Testing
Heavy Duty Testing
Invalid Test
Valid Test
Test Validation
Tech.
EPA Rep.
Man. Rep.
No
Test OK?
Yes

EPA QUALITY MANAGEMENT PROCEDURE

QMP NO.	REVISION DATE
6.5	

SUBJECT: TEST FACILITY SUPPORT SERVICES

I PURPOSE

This QMP outlines the responsibilities and procedures for providing support services to vehicle testing such as chemical analysis, equipment engineering, instrument services, correlation and maintenance and craft services.

II BACKGROUND

A. Extended "down time" created by outside supplier service delays cannot be tolerated and the expense of maintaining duplicate sets of equipment is prohibitive in many cases. It is essential therefore, that a measurement system should be designed to be self sufficient in supplying support services for equipment and instruments used in the system.

B. Responsibilities and procedures used for the support groups are probably the most varied and least defined in measurement systems. This QMP describes support services generally as they exist at a typical government test facility. Development of support service responsibilities and procedures will depend largely on the ability and desire of the Testing Laboratory to invest in support equipment, testing equipment and calibration standards and, in addition, the availability and skill of the personnel in the support group.

III SCOPE OF APPLICATION

A. These responsibilities and procedures generally apply to groups not directly involved in testing a vehicle but in maintaining, repairing, calibrating and correlating equipment and instruments used in the facility. It applies also to groups performing any functions, test or analysis not specifically required by the federal test procedure but necessary for the particular program or organization.

B. Any service related to the instrumentation, equipment, fuels, or gases used in performance of mobile source emission testing is subject to evaluation by Quality Assurance.

C. All maintenance must be authorized by the vehicle test management.

D. Support services may not perform unscheduled services without authorized work order issued by Production Control.

CONCURRENCES	DATE	IMPLEMENTATION
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IV RESPONSIBILITIES AND PROCEDURES

A. Chemical Analysis

1. Generates binary gravimetric gas mixtures to be used as primary standards.
2. Determines purity of gases used in generation of laboratory standards.
3. Determines lead concentration in test fuels.
4. Determines sulfates by wet chemistry.
5. Blends and stores propane used for CVS Tracer gas injections.
6. Performs required calibration of barometers and hygrometers.

B. Quality Assurance

1. Performs audit of gravimetric gas mixtures to assure analysis output validity.
2. Evaluates incoming gases to assure that the desired purity standards are maintained.

C. Equipment Engineering

1. Maintains inventory of all equipment and instrumentation utilized by the Laboratory operations.
2. Issues and controls use of measurement-related equipment.
3. Designs prototype measurement and analytical systems for special contract requirements.
4. Coordinates with Craft Services during production of design equipment.

D. Quality Assurance

1. Coordinates with Equipment Management/Design to assure equipment required for the Measurement System meets contract specifications.
2. Checks design specifications to assure the desired results will be attained.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

E. Instrument Services

1. Performs periodic calibration of chart recorders, temperature recorders and support electronic instrumentation.

2. Performs routine, preventive and emergency maintenance on electronic equipment.

3. Maintains control of all instrument and equipment manuals required for the measurement equipment.

4. Maintains complete file of instrument failures and corrective action.

F. Quality Assurance

1. Reviews and evaluates calibration procedures with reference to data collection and analysis.

2. Reviews maintenance procedures, frequency of repair to assure timely, efficient repairs are accomplished, and verifies the implementation of corrective action where applicable.

3. Reviews manual control file to determine that a complete information file exists.

G. Correlation and Maintenance

1. Performs periodic calibration of the CVS, chassis dynamometers and gas analyzers.

2. Provides gas analysis inspection of incoming gases.

3. Performs CVS Tracer verification, dynamometer calibration verification and NO_x efficiency checks.

4. Updates log books and completes calibration tags correctly.

H. Quality Assurance

1. Reviews and evaluates data collection and curve analysis techniques in calibration procedures to assure the integrity of the operation practices.

2. Validates verification checks performed on the measurement system.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

I. Craft Services

1. Performs equipment modification required to meet current operation requirements.
2. Produces prototype systems under the direction of Equipment Management/Design.

J. Quality Assurance

1. Evaluates modification requirements and witnesses functional operation tests.

EPA QUALITY MANAGEMENT PROCEDURE	QMP NO. 6.6-HD	REVISION DATE

SUBJECT:

DATA VALIDATION

I PURPOSE

This QMP establishes the criteria to be followed in the evaluation of raw measurement data generated from the Heavy Duty Gasoline and Diesel Engine Emission Tests.

II BACKGROUND

A. Experience indicates that data and information generated during mobile source emission testing is subject to error. All raw data must be checked by personnel familiar with the procedure but not directly involved in the performance of a test. The validation procedure must be performed expeditiously, as the test must be validated prior to vehicle release, or in the event of an invalid test, a retest schedule.

B. Data validation may be done manually or automatically by computers programmed to detect omissions or suspect data.

III SCOPE OF APPLICATION

A. All data generated from the various phases of Heavy Duty Engine Emission Tests shall be validated according to prescribed procedures.

B. Any unusual values discovered during the evaluation will be fully documented and examined for validity prior to a rejection decision.

C. Data validation is concerned with the accuracy, precision and completeness of the data, however, this function should not be considered as, or take the place of a data audit by Quality Assurance.

D. Data validation also assists in the preparation and distribution of the forms used in the test facility.

IV RESPONSIBILITIES AND PROCEDURES

A. Data Validation

1. Checks inspection, and engine preparation, and engine check-out information for completeness, authorization, and compliance to specs.

2. Checks analyzer traces for obvious errors and compare chart values with those logged on the Analyzer Read-out form.

3. Checks temperature, engine RPM and load traces for conformance with prescribed cycle conditions.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 3
APPROVED BY:		DATE ISSUED:

IV RESPONSIBILITIES AND PROCEDURES (Continued)

A. Data Validation (continued)

4. Checks for completeness of all required information on data sheet.

B. Quality Assurance

1. Performs audit of test data to assure the required data is complete.

2. Evaluates spurious values discovered by Data Validation to determine if the data is acceptable.

3. In the event of test failures, prepares a Test Condition Report which describes the reasons for rejection and coordinates with other organizations to affect corrective action.

C. Data Validation

1. Submits data to the Data Service for preliminary analysis.

2. Obtains preliminary results and makes final check of data.

3. If errors are discovered, corrections are made and corrected data sheet is re-routed to the Data Service for a new print-out or calculation.

4. Checks off the remaining documentation and enters it in the data file.

5. Requests schedule of retest if test is declared invalid.

6. Releases engine to shipping for return shipment to manufacturer and submits valid data with authorized signature or mark to laboratory operations for distribution.

D. Quality Assurance

1. Reviews and evaluates all heavy duty emission testing procedures with reference to error and bias in collection, handling and analysis of samples.

E. Quality Assurance

1. Reviews all data records at regular intervals for possible human error such as:

a. Failure of technician to record pertinent information.

IV RESPONSIBILITIES AND PROCEDURES (Continued)

E. Quality Assurance (continued)

b. Errors in reading an instrument.

c. Errors in calculating results.

d. Errors in transposing data from one form to another.

e. Errors in keypunching data.

f. Errors in computer tape handling, programming and print-outs.

2. Utilizes statistical sampling and control chart techniques whenever they can be applied advantageously in data verification.

3. Assures corrective action is implemented to prevent recurring errors in data recording and analysis.

F. Data Flow Schematic

See QMP 6.1-HD

QUALITY MANAGEMENT PROCEDURES

SECTION 7.0

FORMS INSTRUCTIONS

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EPA QUALITY MANAGEMENT PROCEDURE	QMP NO. 7.1	REVISION DATE

SUBJECT:
FORMS INSTRUCTION - INSTRUMENT LOAN ORDER

1. FORM NUMBER 7.1:1-31-75

2. FORM USE: QMP 5.1

   2.1 To provide a record of the individual and organization having custodial responsibility for equipment requisitioned from Standards and Calibration Equipment Stores.

3. FORM INSTRUCTIONS

   3.1 The paragraph numbers listed below coincide with the numerals in the blocks in Attachment No. 1.

      1. Man No. - Employee number of the individual requisitioning the equipment.

      2. Control No. - The control number affixed to the equipment being requisitioned; i.e., ACL 81352, ORD 15421, etc.

      3. Orgn. - The organization number of the individual requisitioning the equipment.

      4. Date - The date the equipment is requisitioned.

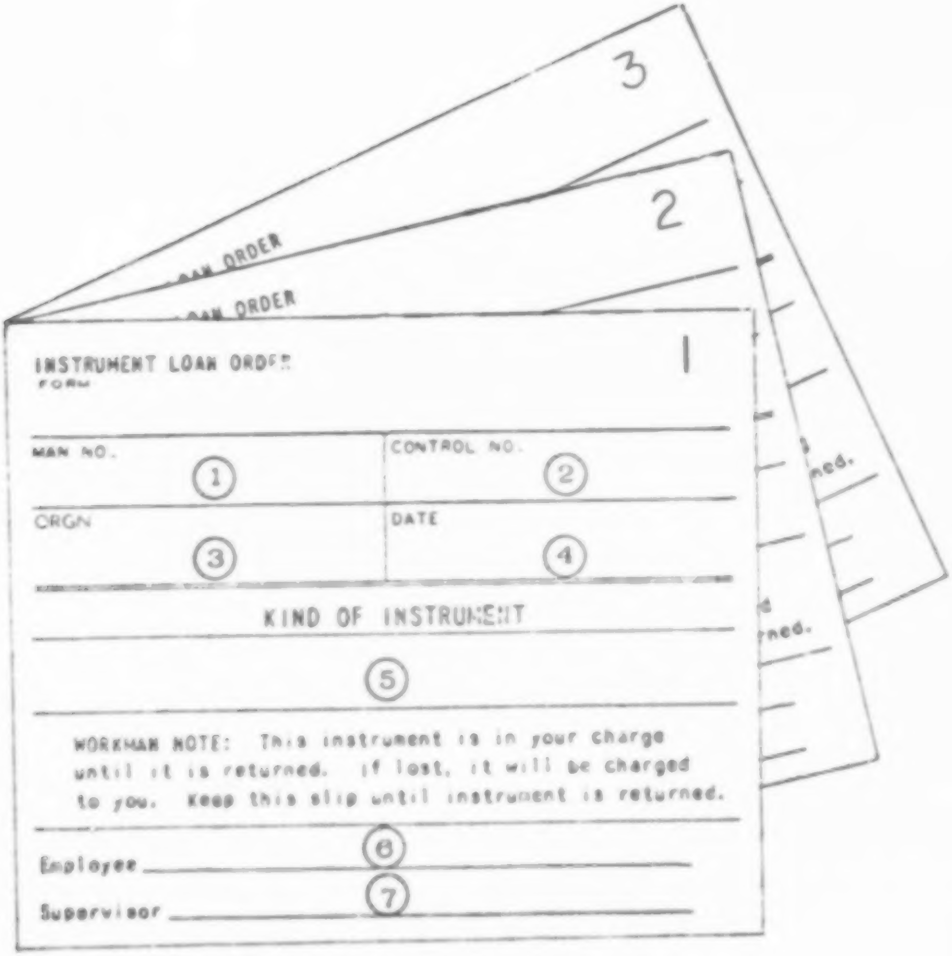
      5. Kind of Equipment - Nomenclature, Mfr. and Model No. of equipment borrowed; i.e., Counter, H P 522B, etc.

      6. Employee - Signature of the individual requisitioning the equipment.

      7. Supervisor - Signature of the requisitioning individual's supervisor.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 1
APPROVED BY:		DATE ISSUED:

QMP NO. 7.1
Attachment No. 1



3

2

INSTRUMENT LOAN ORDER FORM

1

MAN NO. ①	CONTROL NO. ②
ORGN ③	DATE ④

KIND OF INSTRUMENT

⑤

WORKMAN NOTE: This instrument is in your charge until it is returned. If lost, it will be charged to you. Keep this slip until instrument is returned.

Employee ⑥ ____________________

Supervisor ⑦ ____________________

FORM NO. 7.1: 1-31-75

EPA QUALITY MANAGEMENT PROCEDURE	QMP NO. 7.2	REVISION DATE

SUBJECT:

FORMS INSTRUCTION - CALIBRATION CONTROL CARD

1. FORM NUMBER: 7.2: 1-31-75

2. FORM USE: QMP 5.1, 5.3

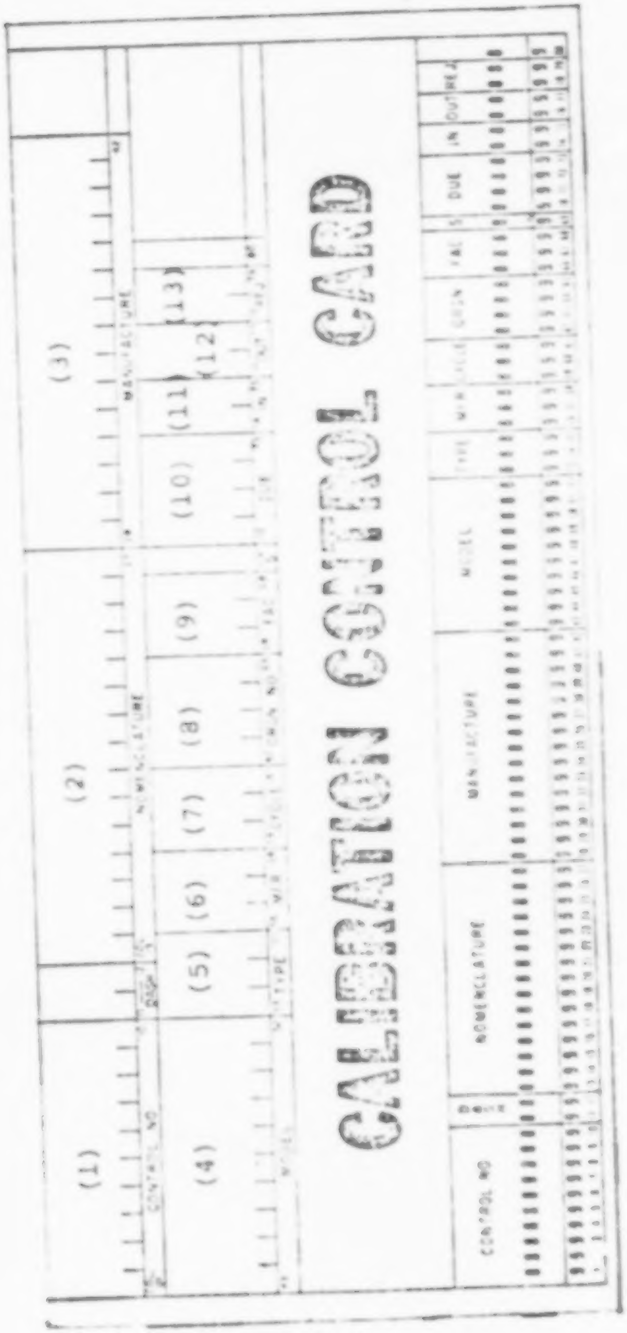
2.1 The calibration control card is used by Records Control and Computer Operations to automatically scan the file for instrument calibration requirements. The information is completed by Records Control and a new card issued by Computer Operations each time a change in calibration status or location is determined.

2. FORMS INSTRUCTION

3.1 The paragraph numbers listed below coincide with the numerals in the blocks in Attachment No. 1.

1. Control Number - The number(s) assigned by Standards and Calibration to equipment to be used in emission testing.
2. Nomenclature - Equipment type, name; i.e., "Power Supply," "Cap Decade," etc.
3. Manufacturer - Manufacturer's name; i.e., "Gen Radio," "Gen Elect.," etc.
4. Model - Equipment model number; i.e., "320A," "CDA5," etc.
5. Type - 1 digit code number specifying equipment type.
6. Mfr. - 3 digit number specifying manufacturer.
7. Cycle - Interval (days) for recalibration (cycle period); i.e., "60", "90", "120", etc.
8. Orgn. No. - Identification of the organization having custody of the equipment.
9. Fac - Identification of the facility where equipment is located.
10. Due - Date the equipment is due for recalibration/maintenance.
11. In. - Number of times instrument was found to be within acceptable tolerance limits when recalibrated.
12. Out. - Number of times instrument was found to be out of tolerance.
13. Rej. - Number of times instrument was rejected when in use and verified as being discrepant.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 1
APPROVED BY:		DATE ISSUED:



CALIBRATION CONTROL CARD

(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
CONTROL NO
NOMENCLATURE
MANUFACTURE
MODEL
CONTROL NO
NOMENCLATURE
MANUFACTURE
MODEL
TYPE
DUE

FORM NO. 7.2: 1-31-75

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 7.3	REVISION DATE

SUBJECT:
FORMS INSTRUCTION - CALIBRATION ORDER

1. FORM NUMBER: 7.3: 1-31-75

2. FORM USE: QMP 5.1, 5.3

   2.1 To recall equipment for periodic calibration/maintenance.

   2.2 To authorize receiving inspection, repair or special calibration of equipment.

3. FORM INSTRUCTIONS

   3.1 The paragraph numbers listed below coincide with the numerals in the blocks in Attachment No. 1.

      1. Control Number - The number(s) assigned by Standards and Calibration to equipment to be used in emission testing.

      2. Nomenclature - Equipment type, name; i.e., "Power Supply," "Cap Decade," etc.

      3. Mfr. - Manufacturer's name; i.e., "Gen Radio," "Gen Elect.," etc.

      4. Model - Equipment model number; i.e., "320A," "CDA5," etc.

      5. Due - Date the equipment is due for recalibration/maintenance.

      6. Cal - Interval (days) for recalibration (cycle period); i.e., "60," "90," "120," etc.

      7. Orgn - Identification of the organization having assignment of the equipment.

      8. Fac - Identification of the facility where equipment is located.

      9. Status - Code number of the equipment status (determined by organization).

      10. Repair - X entered when order is for repairing an item which failed when in use.

      11. Recall - X entered when order is for periodic recalibration/maintenance of equipment.

      12. Buy-in - X entered when order is for receiving inspection of equipment.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 3
APPROVED BY:		DATE ISSUED:

3. FORM INSTRUCTIONS (Continued)

13. Other - entered when order is for services other than 10, 11 or 12 above.

14. Sign - Signature of the individual returning the equipment (Recall Order) or initiating the order for "Repair," "Buy-in," or "Other."

15. Date - Date of signature.

16. Ext - Telephone extension of individual returning equipment, or initiating order.

17. Yes - X entered by individual returning equipment if he wishes it back after recalibration.

18. No - X entered by individual returning equipment if he does not want it back after recalibration.

19. Remarks - Special instructions pertaining to orders for "Repair," "Buy-in" or "Other" when necessary or information that a replacement item has been furnished. Enter "See calibration report" when such a report is generated to support the calibration job.

20. Comp By - Man number of technician completing the work specified by the order.

21. Date - Date work is completed by the technician.

22. In/Tol - X entered if equipment was found to be in tolerance during scheduled recalibration.

23. Out/Tol - X entered if equipment was found to be out of tolerance during scheduled recalibration.

24. MTL Cost - Cost (to nearest tenth of a dollar) of parts used to repair equipment; i.e., "10.5," "1.3," etc.

25. Time Exp - Time spent by technician to complete work.

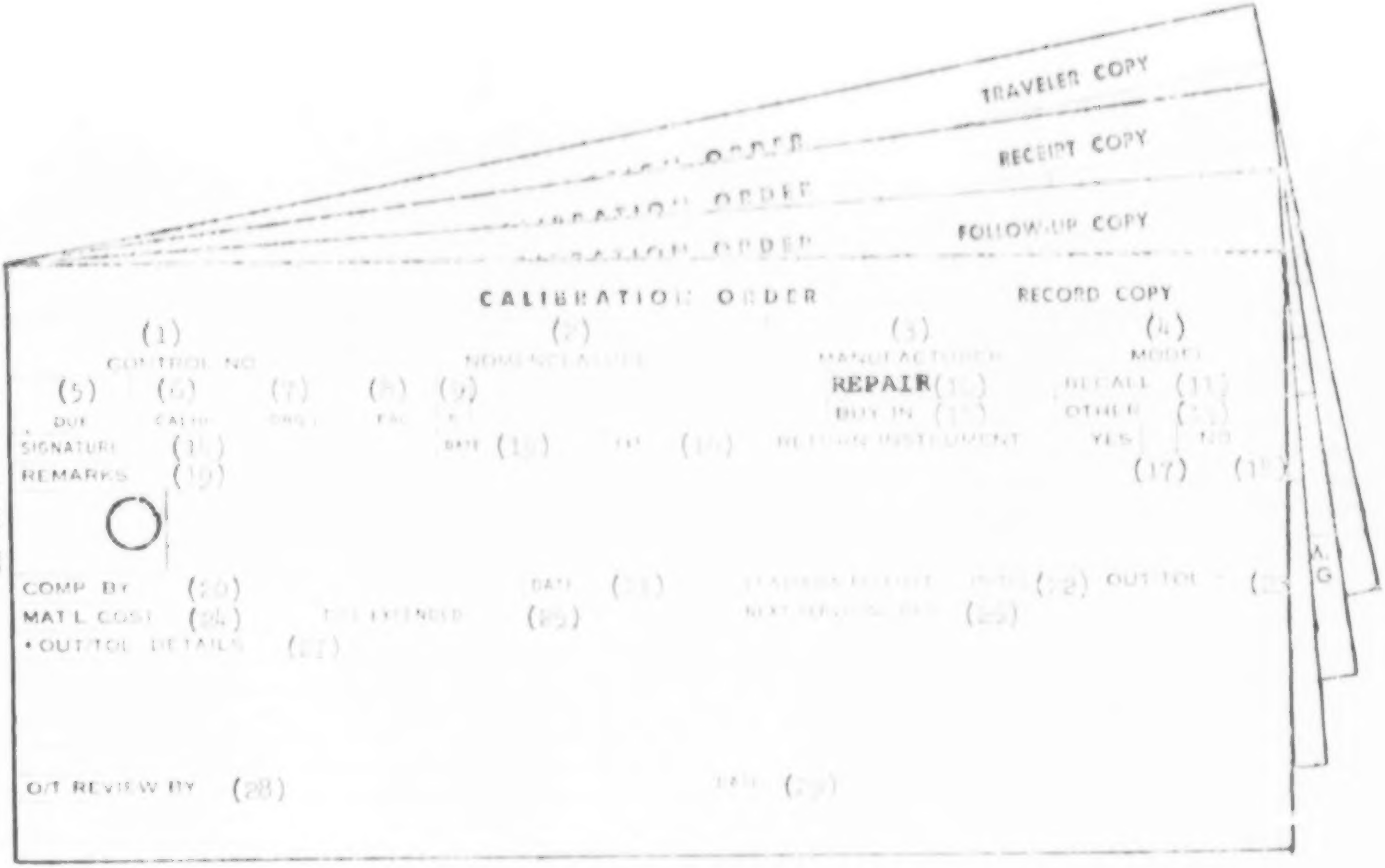
26. Next Servicing Date - Date the equipment will require recalibration (month, date and year).

3. FORM INSTRUCTIONS (Continued)

27. Out/Tol Details - Specific function(s) involved, variables data defining discrepancies and rework performed to correct the condition(s).

28. O/T Reviewed by - Signature of individual evaluating out/tol details and related records to isolate chronic or critical conditions.

29. Date - Date of O/T Review.



TRAVELER COPY

RECEIPT COPY

FOLLOW-UP COPY

CALIBRATION ORDER

RECORD COPY

(1) CONTROL NO
(2) NOMENCLATURE
(3) MANUFACTURER
(4) MODEL

(5) DUE
(6) CALIB
(7) ORG
(8) FAC
(9)

REPAIR (10)
RECALL (11)
BUY IN (12)
OTHER (13)

SIGNATURE (14)
DATE (15)
(16)
RETURN INSTRUMENT YES (17) NO (18)

REMARKS (19)

COMP BY (20)
DATE (21)
(22)
OUT TOL (23)

MAT'L COST (24)
EXTENDED (25)
NEXT DATE (26)

• OUT/TOL DETAILS (27)

O/T REVIEW BY (28)
DATE (29)

FORM NO. 7.3: 1-31-75

EPA QUALITY MANAGEMENT PROCEDURE

QMP NO.	REVISION DATE
7.4	

SUBJECT:
FORMS INSTRUCTION - TEST CONDITION REPORT

1. FORM NUMBER: 7.4:1-31-75.

2. FORM USE: QMP 6.1, 6.6.

2.1 The Test Condition Report (TCR) is used to record details of any failures that occur during Mobile Source Emission Testing.

3. FORM INSTRUCTIONS:

3.1 The paragraph numbers listed below coincide with the numerals in the blocks in Attachment No. 1.

1. Failure - X entered if a test failure has occurred.
2. Void - X entered if a test has been voided.
3. Retest Requested - X entered if a retest has been requested.
4. Name - Name of person originating TCR.
5. Date Submitted - Date TCR was issued.
6. Branch - Identify organization to which originator of TCR reports.
7. Section - Identify section/unit to which originator of TCR belongs.
8. Extension - Telephone extension of originator of TCR.
9. Test Type - X entered in appropriate block to indicate type of test, i.e., Light Duty (LD), Medium Duty (MD), Heavy Duty (HD), or Other Tests.
10. Manufacturer - Vehicle manufacturer's name, e.g., Ford, GM, etc.
11. Identification Number - Vehicle Identification Number.
12. Date - Date failure or voided test occurred.
13. Time - Time of day that failure or voided test occurred.
14. Operator - Name of operator performing test.
15. Equipment Involved in Failure - X entered in appropriate box(es).

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 2
APPROVED BY:		DATE ISSUED:

3. FORM INSTRUCTIONS (continued)

16. Failure Description - Originator writes in a complete description of the failure or condition which caused the test to be voided.

17. Void Point - Identify sequence in test at which failure or void condition aborted the test.

18. Hours Lost - Record time taken to run test up to void point (include preparation time).

19. Corrective Action Taken - Specify corrective action measures taken to preclude recurrence of voided test/failure.

20. Signature - Originator of TER signs.

QMP NO. 7.4
Attachment No. 1

TEST CONDITION REPORT

Failure ___(1)___ Void ___(2)___ Retest Requested ___(3)___

Name ___(4)___ Date Submitted ___(5)___

Branch ___(6)___ Section ___(7)___ Extension ___(8)___

Test Type: (9) ___LD ___MD ___HD ___Other

Manufacturer (10)___ Identification Number ___(11)___

Date ___(12)___ Time ___(13)___ Operator ___(14)___

Equipment Involved in Failure: (15)

___Analysis System ___Recorder ___Bags

___HC ___CO ___NO ___CO_2 ___Temp.

___CVS ___Drivers Trace ___FID

___CVS Counter ___Cold Start ___Hot Start

___Dynamometer ___Other (Specify)

Failure Description ___(16)___

Void Point ___(17)___ Hours Lost ___(18)___
(Include Prep Time)

Corrective Action Taken ___(19)___

___(20)___
Signature

FORM NO. 7.4: 1-31-75

QMP NO. 7.4
Attachment No. 1

TEST CONDITION REPORT

Failure ____(1)____ Void ____(2)____ Retest Requested ____(3)____

Name ____(4)____ Date Submitted ____(5)____

Branch ____(6)____ Section ____(7)____ Extension ____(8)____

Test Type: ____(9)____ LD ________ MD ________ HD ________ Other

Manufacturer ____(10)____ Identification Number ____(11)____

Date ____(12)____ Time ____(13)____ Operator ____(14)____

Equipment Involved in Failure: (15)

________ Analysis System ________ Recorder ________ Bags

________ HC ________ CO ________ NO ________ CO_2 ________ Temp.

________ CVS ________ Drivers Trace ________ FID

________ CVS Counter ________ Cold Start ________ Hot Start

________ Dynamometer ________ Other (Specify)

Failure Description ____(16)____

Void Point ____(17)____ Hours Lost ____(18)____
(Include Prep Time)

Corrective Action Taken ____(19)____

____(20)____
Signature

FORM NO. 7.4: 1-31-75

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 7.5	REVISION DATE

SUBJECT:
FORMS INSTRUCTION - EQUIPMENT/PROCEDURE CHANGE NOTICE

1. FORM NUMBER: 7.5:1-31-75.

2. FORM USE: QMP 3.2, 6.2.

2.1 The Equipment/Procedure Change Notice is used to document and implement changes in practices or equipment specified in Test Procedures (TP) and Quality Management Procedures (QMP) used in the Mobile Source Emission Measurement Program.

3. FORM INSTRUCTIONS

3.1 The paragraph numbers listed below coincide with the numerals in Attachment No. 1.

1. Originator - Name of person originating EPCN.
2. Phone Ext. - Phone extension of originator.
3. Date Required - The date EPCN is needed.
4. Type of Change - "Equipment" X entered if equipment change, "Procedure" X entered if procedure change, "Other" X entered for any other type of change.
5. References - Identify referenced procedures, specifications, etc.
6. Change Requested By - Identify person requesting change.
7. Purpose of Change - Specify reason for change.
8. Description of Change - Describe change, and attach details, specification, or drawings if necessary.
9. Effectivity - Effective date or serial number, etc., as determined by Laboratory Operations.
10. Duration or Extent of Use - "Permanent" X if change is permanent, "Temporary" X if temporary change only and indicate date effectivity expires.
11. Areas Affected by Change - Indicate areas affected by change by marking X in appropriate boxes.
12. Reviews and Approvals - Reviewers/Approvers sign and enter date of review/approval.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 2
APPROVED BY:		DATE ISSUED:

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3. FORM INSTRUCTIONS (continued)

13. QC/QA Manager - Signifies approval and date approved.

14. Lab Branch Chief - Signifies approval and date approved.

15. Date - Date EPCN is initiated.

16. EPCN No. - Reference number assigned by Document Control.

17. Page _______of_______-Page number.

QMP NO. 7.5 Attachment No. 1

EQUIPMENT/PROCEDURE CHANGE NOTICE

DATE (15)

EPCN NO. (16)

PAGE ___ OF ___ (17)

1. ORIGINATOR (Name)

2. PHONE EXT.

3. DATE REQUIRED

4. TYPE OF CHANGE ☐ EQUIPMENT ☐ PROCEDURE ☐ OTHER

5. REFERENCES

6. CHANGE REQUESTED BY (Name)

7. PURPOSE OF CHANGE

8. DESCRIPTION OF CHANGE (Attach details, specifications, or drawings if necessary)

9. EFFECTIVITY (Date or Other)

10. DURATION OR EXTENT OF USE (See 9.) ☐ PERMANENT ☐ TEMPORARY ____________

11. AREAS OF MSAPC AFFECTED BY THIS CHANGE

☐ LDT ☐ E&D ☐ CHEM ☐ LAB ☐ QC/QA ☐ CSD

☐ HDT ☐ I&E ☐ C&M ☐ DATA ☐ ECTD

☐ OTHER ____________________

12. REVIEWS AND APPROVALS

REVIEWED BY	DATE	APPROVED BY *	DATE
A.		F.	
B.		G.	
C.		H.	
D.		I.	
E.		J.	

* (IF NOT APPROVED, PLEASE DISCUSS DETAILS ON REVERSE SIDE)

ALL REVIEWS AND APPROVALS HAVE BEEN RECEIVED AND DOCUMENTED	13. QC/QA MANAGER	DATE

FINAL IMPLEMENTATION

THE PROVISIONS OF THIS EPCN ARE APPROVED AND HEREBY IMPLEMENTED	14. LAB BRANCH CHIEF	DATE

FORM NO. 7.5: 1-31-75

DISTRIBUTION: ORIGINATOR
QC/QA OFFICE
DIVISION FILES
AREAS AFFECTED

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 7.6	REVISION DATE

SUBJECT:
FORMS INSTRUCTION - QMP CHANGE AND REVISION SUMMARY

1. FORM NUMBER: 7.6:1-31-75.

2. FORM USE: QMP 3.1.

   2.1 To provide a summary of changes and revisions to QMP's.

3. FORM INSTRUCTIONS

   3.1 The paragraph numbers listed below coincide with the numerals in the blocks in Attachment No. 1.

      1. EPCN Number - The Equipment/Procedure Change Notice file number assigned by Document Control on QMP Form 7.5, which accompanies all changes and revisions to QMP's.

      2. Date - Date as indicated on EPCN.

      3. Procedure Number - QMP number of affected procedure.

      4. Procedure Revision Date - Revision Date shown in QMP.

      5. Procedure Title - Subject Title of QMP.

      6. Entered By - Name of QMP manual holder recording change.

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 1
APPROVED BY:		DATE ISSUED:

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QUALITY MANAGEMENT PROCEDURES

Change and Revision Summary

EPCN Number	Date	Procedure		Procedure Title	Entered By
		Number	Revision Date		
(1)	(2)	(3)	(4)	(5)	(6)

FORM NO. 7.6: 1-31-75

EPA QUALITY MANAGEMENT PROCEDURE	**QMP NO.** 7.7	REVISION DATE

SUBJECT:
FORMS INSTRUCTION - REJECTION REPORT

1. FORM NUMBER: 7.7:1-31-75

2. FORM USE: QMP 4.2

2.1 The Rejection Report is used to document, identify and withhold discrepant materials and equipment.

3. FORM INSTRUCTION

3.1 The paragraph numbers listed below coincide with the numerals in the blocks in Attachment No. 1.

1. Part Number - Enter drawing/specification number of item being rejected.

2. Part Name - Noun description of item being rejected.

3. Supplier/Manufacturer - Name of supplier/manufacturer if procured item.

4. Quantity Rejected - Number of items being rejected.

5. Date Rejected - Date items were rejected.

6. Contract - Contract number or code.

7. Purchase Order Number - Purchase Order identification number, if procured item.

8. Receiving Report-Number - Receiving Report identification number if procured item.

9. Item Number - Item number of discrepancies starting with one (1) and progressing sequentially. Do not list more than one type of discrepancy under one item number.

10. Discrepancies - Describe discrepancies, itemizing by type of discrepancies.

11. Rejected by - Name of person inspecting and rejecting discrepant materials/equipment.

12. Date - Date inspector signs off in (11).

CONCURRENCES	DATE	IMPLEMENTATION
PREPARED BY:		PAGE 1 OF 2
APPROVED BY:		DATE ISSUED:

3. FORM INSTRUCTION (continued)

13. Supervisor Approval - Inspector's supervisor reviews rejection and signifies approval by signing here.

14. Date - Date supervisor signs off in (13).

15. Quality Assurance Approval - Quality Assurance reviews rejection and signifies approval by signing here.

16. Date - Date Quality Assurance signs off in (15).

17. Disposition - When designated authority or material review board determines disposition of rejected material/equipment, check appropriate box (if "other" specify type of disposition made).

18. Failure Analysis Required - Check box if a formal failure analysis report is required, and upon receipt of the report enter identifying reference number.

19. Corrective Action - Statement of corrective action taken to preclude recurrence of discrepancy.

20. Quality Assurance Approval - Quality Assurance Manager/Supervisor reviews Rejection Report and Corrective Action statement and signifies approval by signing here.

21. Date - Date Quality Assurance Manager/Supervisor signs off.

QMP NO. 7.7
Attachment No. 1

REJECTION REPORT

NO. 11101

PART NUMBER (1)	PART NAME (2)	SUPPLIER/MFR (3)

REJECTED				
QUANTITY (4)	DATE (5)	CONTRACT (6)	PURCHASE ORDER NO. (7)	REC. REPORT NO. (8)

ITEM NO.	DISCREPANCIES (10)
(9)	

REJECTED BY (11)	DATE (12)	SUPERVISOR APPROVAL (13)	DATE (14)	Q.A. APPROVAL (15)	DATE (16)

DISPOSITION (17)

USE AS IS ☐

RETURN TO SUPPLIER ☐

OTHER (SPECIFY)

☐ CHECK IF FAILURE ANALYSIS REQUIRED (18)

FAILURE ANALYSIS REPORT NO. ____________

CORRECTIVE ACTION (19)

Q.A. APPROVAL (20) DATE (21)

FORM NO. 7.7: 1-31-75